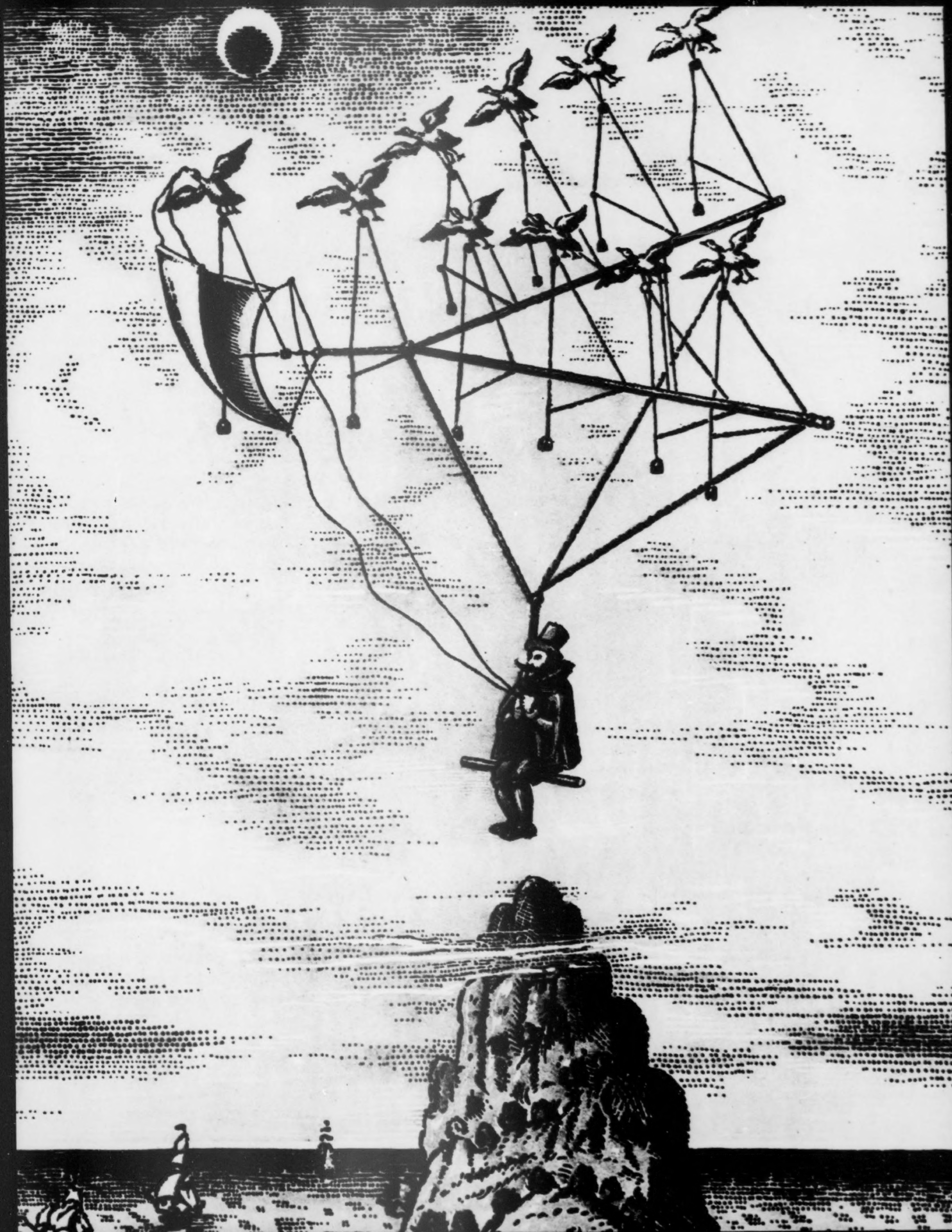


Air & Space

National Air & Space Museum
Smithsonian Institution
Vol. 6, No. 3 Spring 1983



Builders and Dreamers

Air & Space

National Air and Space Museum
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Air & Space, a mini-magazine for educators, is published four times during the school year as an outreach of the National Air and Space Museum, Smithsonian Institution, Washington, D.C.

Air & Space combines information from many sources for a condensed overview of the history, science, technology, and social impact of selected aviation and space subjects.

Air & Space

Address all communications to: *Air & Space*, Room P-700, Education Services Division, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560. For changes or corrections of address, write to *Air & Space* at the above address, and include the 6-digit subscription number on your mailing label.

There is no charge for *Air & Space*. The magazine is not available by paid subscription.

Commercial interests and other publications wishing to reprint material should mail requests to the above address.

Back issues of *Air & Space* are available on microfiche or photocopy through University Microfilms International, Inc., 300 N. Zeeb Road, Ann Arbor, Michigan 48106.

For brevity, the National Air and Space Museum is often referred to in these pages as NASM. The National Aeronautics and Space Administration is NASA.

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Cover Photo: *One of the early science-fiction fantasies, The Man in the Moone, by Francis Godwin, Bishop of Hereford, was published in 1683. In this engraving, Godwin's hero, Domingo Gonsales, harnessed 25 geese to his flying apparatus that would enable him to reach the Moon.*

Briefing

Walter J. Boyne
Acting Director, NASM

In recent years, aircraft and spacecraft have become so complex that individual designers are only rarely credited with a product. Some towering geniuses, like Kelly Johnson, are still given this honor, but in modern industry it is not at all like it was in the beginning, when men like Sir Geoffrey de Havilland, T.O.M. Sopwith, Glenn Curtiss, Grover Loening, and others put such a distinctive stamp upon their designs that they were identifiable at a glance.

There are very good and obvious reasons for this; aircraft and spacecraft are infinitely more complex, often being more of an assemblage of many intricate systems—hydraulic, pneumatic, electric, navigational, etc.—than being “just” a flying machine. Indeed, modern programs are often accomplished by a highly integrated engineering team using computers that permit multiple, simultaneous approaches to the solution of design problems.

In the early days of aviation (and as we'll see later, even now) it was the individual that counted. Aircraft during what is referred to as the “Golden Age” were often designed by an individual whose personality flowed into his creation just as an artist's flows into his paintings. It's interesting to review, for example, the aircraft designed by Sir Sidney Camm, the great genius of Hawker aircraft. If one looks at profiles of his aircraft, beginning with the early biplane fighters and continuing down to post-World War II aircraft, his signature is clearly defined. The late Ben Kelsey, our beloved Lindbergh Scholar, was both a formidable engineer and a pilot, and he often remarked that what was true of the external features—the distinctive rudders of de Havilland types, the flowing lines of Ed Wells, the sleek streamlining of Dick Palmer—was often true of the internal structures. Engineers proved themselves by following certain practices and repeating them in design after design. The best example is Barnes Wallis with his totally proprietary “geodesic” construction. Others who left a distinctive structural engineering design include Alexander Kartveli of Thunderbolt fame, George Page at Curtiss, and of course John Northrop who managed to be unique in both wood and metal structures.

This singularity of design began to disappear in the late 1950s, but it has recently reemerged in what can only be called the second “Golden Age of Aviation.” As inflation and complexity hiked up the price of all aircraft, including the smallest Piper Cub types, would-be pilots and engineers began to seek their own solution in homebuilt aircraft, hang gliders, ultra lights, and in some instances, restoring older classics. As a result, one finds reappearing the phenomenon of individual genius imprinted upon design. Certainly as diverse as his stable of designs is, Burt Rutan's airplanes could never be mistaken for anyone else's. Molt Taylor and Ladis Pazmany are other examples. There is some basic urge within mankind to leave a visible trace, and it manifests itself in aircraft design just as it does in sculpture or music. Without this wonderful force, not only aviation, but every creative endeavor would be a lesser thing.

Francis Arcier, Designer of Aircraft

Richard S. Allen
Aviation Historian

He was a quiet reserved man—an Englishman with a French name. He had a lean face, a pencil mustache, an aquiline nose, and was prematurely bald. Those who knew him remember an intense concentration in his dark gray eyes. His clipped British accent belied his love of American slang. He liked to play golf, enjoyed all kinds of music, and was an excellent pianist.

A. Francis Arcier was one of a distinguished group of aircraft engineer-designers who never got his name on an airplane. Despite his long association with the aviation industries of two continents, the accomplishments of this modest technical expert have been neglected in the face of accounts of more flamboyant aircraft builders. Yet, over a period spanning three decades, Arcier was an important contributor to America's development of aircraft in both war and peace.

Born in 1891, Arcier was a native of London, where his French father presided over a fashionable *salon de coiffure*. Though his mother was English, Arcier had French tutors and was sent to a boarding school in Boulogne, with thoughts of a career as a diplomat.

In France the bilingual schoolboy met Wilbur and Orville Wright who were making demonstration flights with their newly revealed aircraft. The British Foreign Service lost a potential ambassador when Arcier became fascinated with the possibilities presented by flying. From then on his thoughts,



Designer Francis Arcier, age 27, readies for a test flight in the Handley Page V/1500 bomber, 1918. This plane was designed in secrecy by George Volkert and Arcier to be capable of flying to Berlin and back with a 3400-kg (7500-lb.) bomb load. A four-engined behemoth, it was first flown by American test pilot Clifford Prodder with Arcier beside him shivering in the cold open cockpit.

dreams, and energies were concentrated on engines, wing structures, controls, and the new science of aviation.

Back home in England, Arcier acquired a short technical education, followed by two years apprenticeship at the Aster Engineering Company in Middlesex. At Aster, Arcier learned mechanical drawing, the quirks of internal combustion engines, and the operation of a practical machine shop.

What spare time his arduous apprenticeship afforded him found the budding engineer, his outing cap reversed, at the wheel of a racing car competing at the famous Brooklands track and in various road races.

By 1911 new aircraft and the engines to power them were rapidly being developed in England and France. Arcier's fluency in both languages was a distinct asset, and he became associated with Gustave Eiffel, the French bridge engineer. Eiffel needed data on wind shear for his bridge designs, so he built a wind tunnel in Paris within sight of his famous tower. Recording the tests run in this howling vortex gave young Arcier his initial understanding of aerodynamics.

Theory had to be supplemented by practice. Arcier was briefly employed as a junior draftsman by the British and Colonial Aeroplane Company. This firm had a flying school at Upavon where their employee finally got the actual sensations of being borne aloft with the wind in the wires. Arcier soloed in a Bleriot monoplane at Hendon Aero-

drome in May 1912 and then was able to act as an instructor while perfecting his flying skills. He logged time in many of the early makes of aircraft: Bleriot's, Avros, Wrights, Caudrons, and Farmans—the cream of the output of three nations.

In July 1914, the 23-year-old engineer-aviator was issued his F.A.I. Certificate. He had just begun working as a test pilot for Handley Page, Ltd., at Cricklewood, northwest of London. Soon he became co-designer with George Volkert on Handley's stepped-up program for building military aircraft.

The company built bombers, which stemmed from an Admiralty request to produce a "bloody paralysing" for overseas patrols. During World War I, Volkert and Arcier designed the Handley Page O/100 and O/400 biplanes, Britain's standard night bombers. Arcier contributed a patented bomb release and made the 30-m (100-ft.) wings fold for easier storage.

The successful "bloody paralysing" led to a hush-hush assignment for the designers in 1917. They were to produce an even bigger bomber, capable of flying to Berlin and back with a 3400-kg (7500-lb.) bomb load. A four-engined behemoth, the V/1500 came off the Volkert-Arcier drawing boards and took shape in secrecy. Britain's largest aircraft up to that time, it was first flown by American test pilot Clifford Prodder with Arcier beside him shivering in the cold open cockpit. Though produced

too late to attempt its mission of bombing the German capital, the plane introduced the tail defense gun position for bombers and pioneered the policy of long-range strategic bombing.

After the armistice, an abortive attempt to fly the Atlantic with a modified Handley Page V/1500 brought Francis Arcier to the U.S. in April 1919. When flight plans were cancelled, he toured the country and decided to stay.

In a day when an entire "engineering staff" consisted of one man in a tiny office with barely room for a drafting kit, Arcier became "chief engineer and designer" for the Witterman-Lewis Aircraft Company. This was a new organization with a factory in Teterboro, New Jersey. The chief engineer's initial work was the redesign and conversion of war-surplus De Havilland DH-4s for transport of the U.S. mails. In addition, Arcier drew up plans for a cabin transport plane, a pilotless aircraft, and the tail surfaces of a non-rigid dirigible. Witterman also employed another English designer, Walter Barling, whose prototype of a huge triplane bomber proved far short of U.S. Army expectations. The financing of this bomber forced the Witterman company into bankruptcy.

The versatile Arcier was still in Teterboro running the plant for the receivers when a new contingent of designer-manufacturers arrived from overseas. These included the gifted, mercurial Anthony H.G. Fokker and quiet, practical Robert B.C. Noorduyn, the two Dutchmen who soon succeeded in making "Fokker" as big a name in American aircraft manufacture as it had been in Germany during World War I.

When Fokker's Atlantic Aircraft Corporation bought the moribund Witterman factory, it inherited Arcier who was appointed both Chief Engineer and factory manager. His first contribution was the design of 100 De Havilland DH-4m2s, in which the wooden fuselage components were to be replaced by steel tubing.

For three years, while Atlantic/Fokker was at its peak as a major American aircraft builder, Arcier was their technical manager. He brought much to the design and ultimate success of the *Fokker Universal* and *Super-Universal*, developed by Noorduyn in the U.S., independent of Dutch precedents. The famous Fokker FVII-3m trimotor airliner was another of his responsibilities. The aircraft used by Richard E. Byrd in the Arctic and for spanning the Atlantic, by Army officers Carl Spatz and Ira Eaker for a record endurance flight, and by the Australian Charles Kingsford-Smith to circle the globe all saw Arcier as engineering copilot at their controls during their test flights. His reputation as "one of the very best aeronautical engineers in the United States" quickly grew, not by self-aggrandizement but by demonstrated ability.

Arcier left Fokker in 1928 to become Vice-President and Chief Engineer of the new General Airplanes Corporation of Buffalo, New York. At General, he was to design, build, and test airplanes structurally and in flight, and see them through to final approval and certification by the Department of Commerce.

A one-man dynamo of activity, Arcier was financially involved with General Airplanes. He is remembered there for his freehand sketches of his ideas, thus communicating his thoughts to his associates with great clarity.

In a mere eighteen months with General, Arcier developed four different aircraft, the best-known being his *Aristocrat*, a three-place cabin monoplane that sported an innovative cantilever landing gear and folding wings. General Tire & Rubber Company bought a fleet of them for an advertising tour, and another was presented to Admiral Byrd to take to the Antarctic.

Unhappily, after building over 50 airplanes, the General company succumbed to the market collapse of 1929, and Arcier lost his investment. Despite the depressed state of the economy, Ar-

cier joined the Waco Aircraft Company as Chief Engineer/Designer in May 1930. Located in Troy, Ohio, Waco was a well-established firm whose planes were sold worldwide. Arcier commuted to the factory from Dayton, the home of the Wright Brothers who had been his inspiration 25 years before.

At Waco he was again responsible for all the dream-to-reality details of the company's airplanes. A colleague was later to remark: "Francis is, himself, a whole design team." For 17 years he continued with accepted procedures putting out about 40 different models of Waco biplanes, the majority of which went into production.

With the outbreak of World War II, Arcier went back to the design of monoplanes. He discarded thoughts of engine weights and performance, for these ships were gliders; the big, slab-sided aerial boxcars that were to carry men and supplies for the invasions of Sicily, Normandy, Holland, Luzon, and Burma. He set to work with wind tunnel models in June 1941, and within a year his two gliders were accepted for quantity production. In all, some 19,400 of Arcier's CG-3s and CG-4s (Cargo Gliders) were built by 17 contractors, 1077 of them by Waco.

The engineer was next asked to develop a 30-place transport glider with a 26-m (85-ft.) wingspan and finally an improved 2-ton model. The prodigious work done by gliders in winning World War II has only recently been recognized, along with Arcier's designs of the best of them.

War-time boom was followed by peace-time bust. Arcier's only post-war design was the promising Waco "W" or *Airistocrat*, an unconventional four-place cabin plane emphasizing safety and ease of handling. Only the prototype was built before Waco abandoned airplane building in 1947.

In supposed retirement, the prolific plane-maker was soon invited to serve as advisor to the Chief of the Intel-



Another Arcier designed aircraft, the General Airplane Corporation Sedan, the *Aristocrat* of 1928, was a three-place cabin monoplane, featuring folding wings for ready storage. Arcier is shown standing second from left.



Top: Arcier was Atlantic/Fokker's technical manager during its peak as a major American aircraft builder. He brought much to the design and ultimate success of the Fokker Universal (like the one above) and Super-Universal, developed by Noorduyn in the U.S., independent of Dutch precedents.



Left: A typical Waco Biplane designed by A. Francis Arcier, this model EQC-6 was flown by Western Air Express in 1937.

Bottom: At the beginning of World War II, Arcier designed gliders—big, slab-sided, aerial box-cars—that carried men and supplies to the invasions of Sicily, Normandy, Holland, Luzon, and Burma. This Waco CG-4A is one of the 19,400 of Arcier's CG-3s and CG-4s built.



ligence Department of the USAF Air Materiel Command. Arcier, whose experience ranged from box kites to jets, made reports on the design of foreign aircraft and analyzed the technical intel-

ligence of other nations. He was awarded the Air Force's highest Civilian Service citations.

A. Francis Arcier devoted all his working life to the study, development,

and use of aircraft. Many planes that first took shape on his drafting table are still flying today. ■

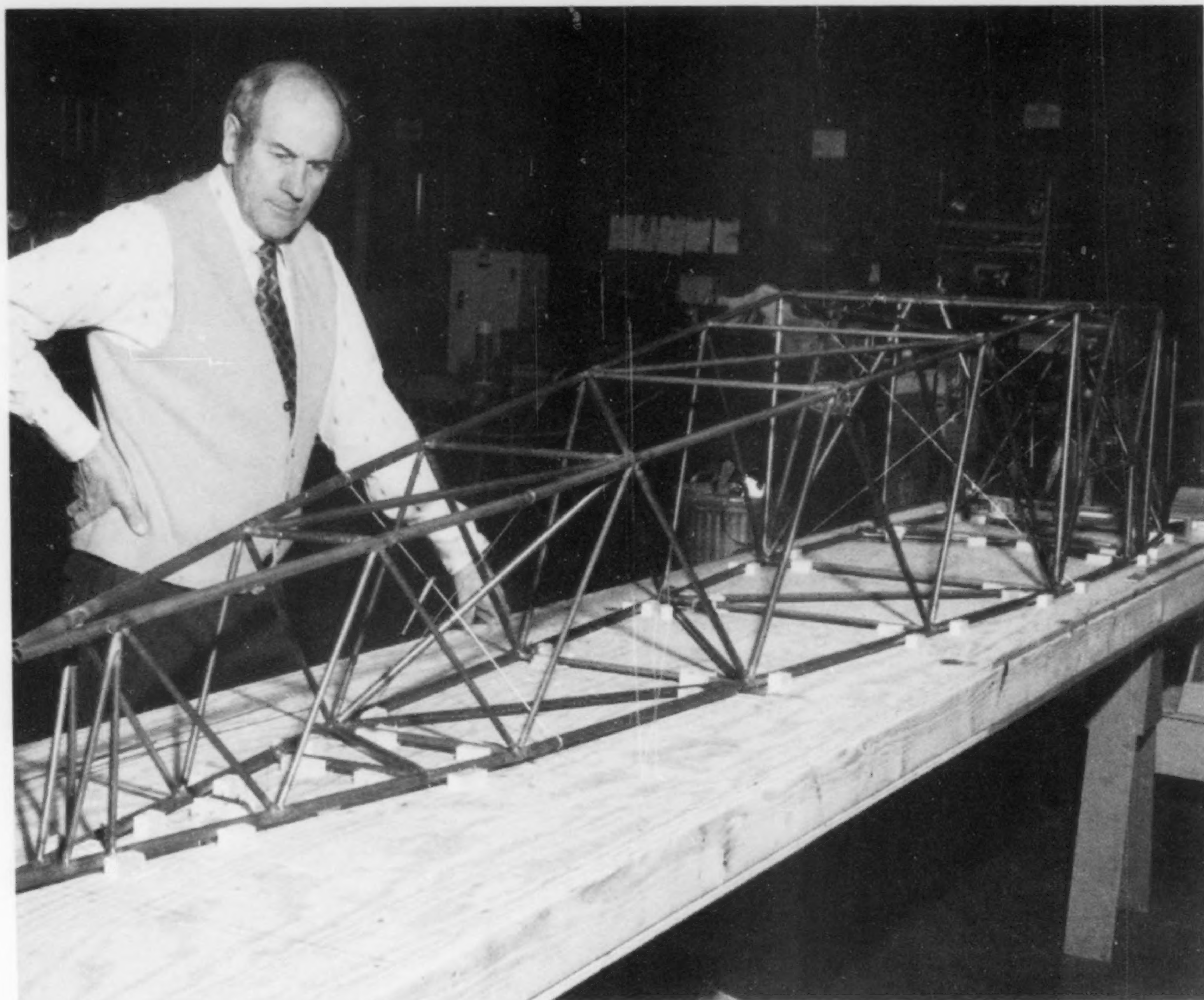
Wings on Dreams

Paul H. Poberezny
Founder & President
Experimental Aircraft Association

If there were an official motto for the EAA, it would be "Wings on Dreams." That is, after all, what the sport aviation association has been doing for the past 30 years . . . putting wings on dreams. Today, there are nearly 100,000 active EAA members worldwide who fly, build, restore, or just plain love airplanes. Their enthusiasm for aviation extends to flying machines of every conceivable size, shape, and description. Currently, there are about 12,000 very special and personal airplanes in America. They were literally built at home.

Throughout aviation's short history, America has been on the cutting edge of aeronautic and aerospace technology. It is, however, ironic that while we have been able to land men on the Moon and bring them safely home, the average American has not been 152 m (500 ft.) above the ground. This, sometimes, leads to certain misconceptions that need to be challenged. First, an experimental aircraft is not constructed of bits of tubing found on a junk heap with perhaps an old bedsheet stretched across the wing. Homebuilt aircraft are very carefully and professionally designed, built, and maintained. They must, of course, pass stringent Federal Aviation Administration (FAA) requirements to be certified as airworthy. Amateur-built aircraft are classified as "experimental" simply because the airplanes fit best into that category under the rather complex FAA regulations.

Second, some people believe that amateur-built aircraft are somehow less professionally constructed than those assembled in commercial airplane factories. The word "amateur" comes from the latin root meaning love. Amateur builders put a great deal of love, time,

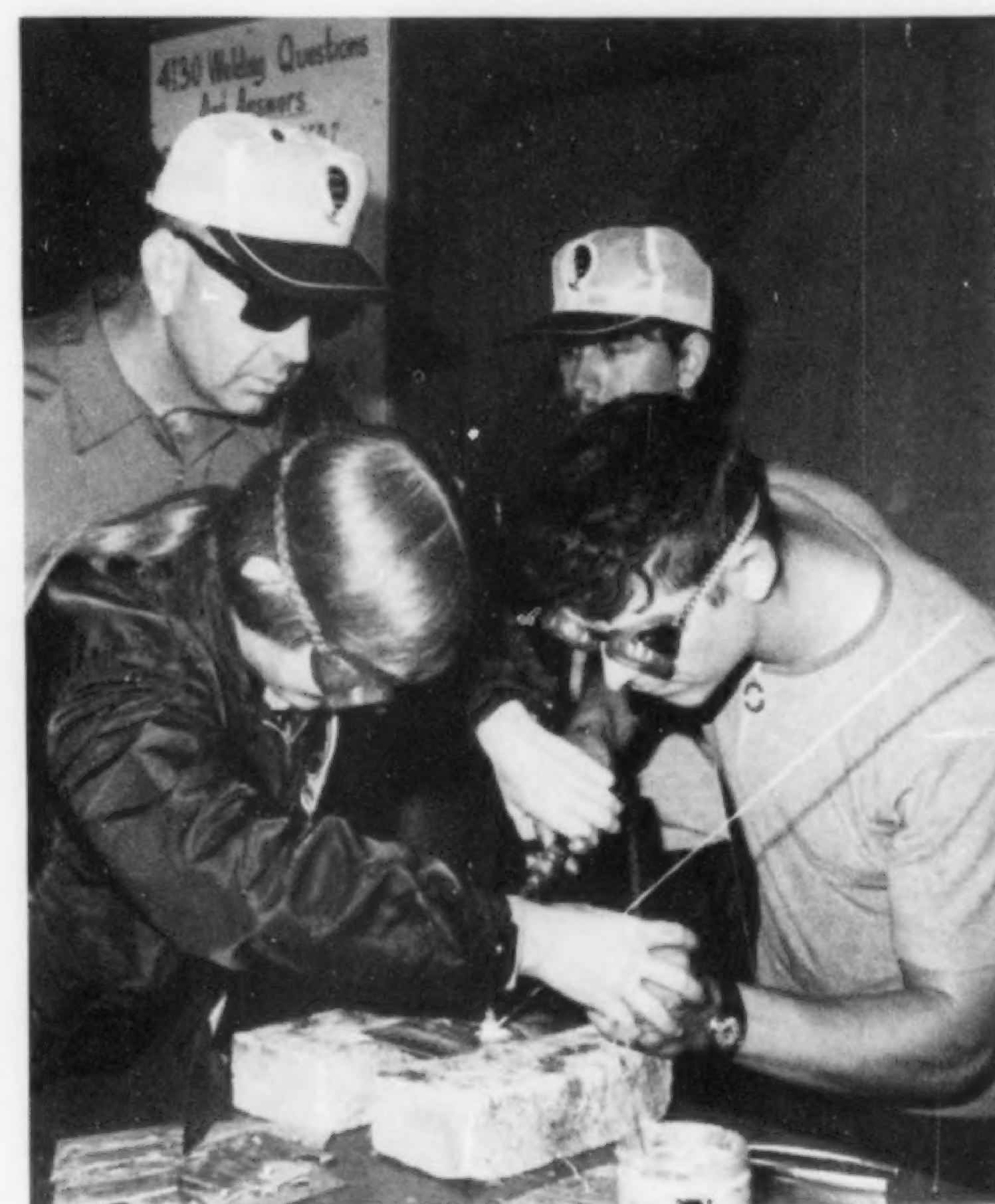


Paul Poberezny inspects the Pober Pixie fuselage in the EAA Aviation Foundation Museum workshop. Poberezny designed the Volkswagen-powered Pixie for Project Schoolflight, which allows hundreds of young people nationwide to participate in constructing an airplane. The Pixie is the second "slowest" flying design available to homebuilders.

dedication, and perseverance into their projects. An airplane built by "amateurs" can be far superior to one manufactured by assembly line employees who may or may not look upon their work as "another job."

Having both designed and built several aircraft myself, I have a deep understanding of the grave responsibilities involved. For instance, the designs for two of my homebuilts, the Pober Pixie and Acro-Sport, are as safe, complete, and structurally sound as I could possibly make them. I am sure that most, if not all designers accept this very serious responsibility.

To the consternation of several teachers, I began doodling airplane drawings in grade school. Those doodles became full-blown designs about the time I reached high school. Many aircraft influence an aircraft designer, for from each design one seems to capture an idea from which to start or improve on. The Pober Pixie was no different and is also the result of the late Ed Heath's influence on me. (Heath inspired many light plane designers and homebuilders of the 1930s, who had little funds and a great desire to fly.) With pencil and paper in hand, sketches grew into drawings and drawings into an airplane—the Pober Pixie—high-wing, single-place, parasol sport plane. This plane has sufficient wing area to enable it to operate out of small airports and can be operated with lower horsepower at a greater degree of safety. The lines are very similar to the last design



Building a plane is many small jobs that involve several skills and trades as well as discipline. Here, under the watchful eye of the EAA Tech Reps, students learn aluminum welding techniques.

of a long list of Heath's accomplishments. The plan form of the tail group, the full span ailerons are a reminder of this.

In those days, I learned some very important lessons about both designing and homebuilding. Basically, anyone who intends to build his own airplane needs to read everything available on the subject and to talk to as many experienced homebuilders and designers as possible. The opportunities for ex-



Paul H. Poberezny (foreground) test flies the Acro Sport, which he designed for several purposes but mainly for use in schools—high school industrial arts programs, Civil Air Patrol groups, etc.

changing information on designs and homebuilt projects are far more extensive today than they were 30 years ago when EAA was founded.

A small group of homebuilders was at the core of the EAA when it was formed in 1953. Although EAA has grown and evolved, the amateur-built movement is still an important part of the Association. Today's homebuilt aircraft are the direct descendants of the Wright Flyer, and the homebuilders themselves are a reflection of America's unique and precious heritage of personal flight. Observers of the aviation scene are sometimes surprised to learn that more than a few of these amateur-built airplanes were completely constructed by high school students through Project Schoolflight.

Project Schoolflight is sponsored by the EAA Aviation Foundation (its non-profit arm), which also maintains an air museum, sponsors aviation research and development, produces forums and seminars on aviation technology and homebuilding, and cosponsors the world's largest aviation event—the annual Fly-in Convention in Oshkosh, Wisconsin. One of the Foundation's most important outreach programs, Project Schoolflight allows hundreds of young people across America to participate in constructing an airplane, such as the EAA Acro-Sport. It was designed for several purposes but mainly for use in schools—high school industrial arts programs, Civil Air Patrol groups, etc. Building a plane is not a big job; it is many, many small ones that involve several skills and trades as well as disci-

pline. But more importantly, the students involved come away from their work with a sense of greater potential and a far deeper sense of responsibility. After all, a human life will depend upon their completed project.

Project Schoolflight began in 1955 at St. Rita's High School in Chicago when an aircraft I designed was built by some of their students. I realized the potential of using an airplane as an educational tool at that time. Students building one are exposed to many different facets of construction such as sheet metal work, woodworking, welding, covering techniques, blueprint reading, mechanical drawing, engine work, and hydraulics. Aircraft and aviation have always been synonymous with high quality and standards in craftsmanship. Quality is the one item that is in the forefront of aircraft construction and is many times lost in today's age of machines and gadgetry. Quality and pride of craftsmanship are extremely important results of Project Schoolflight. It is through this program that students, with or without a background or particular interest in aviation, become more knowledgeable about and more dedicated to this nation's future in aeronautics.

Today, nearly 500 aircraft are under construction in various schools with approximately 175 planes already completed. The program is growing at a rate of about 70 new airplanes per year. It is the fastest growing aviation education program in the world. Each year, more high schools, technical schools, and colleges see the benefits derived from the Project Schoolflight curriculum. Some

benefits are not entirely related to aviation. A teacher in Milwaukee says, "I started with 7 students in my aviation class. After Project Schoolflight was initiated, that jumped to 70. We have seen an improvement in enrollment, attendance and student attitudes which have been very beneficial in all of the student's classes."

Involvement with Project Schoolflight begins with a set of EAA plans for its biplane, the Acro Sport I, the Acro Sport II, or the Pober Pixie. EAA assists the school with information and updates in the form of a newsletter. Frequently, members of one of the local chapters get involved; designees assist by inspecting construction before FAA airworthiness certification. In addition, nearly 1500 local volunteers serve as "Tech Reps." They provide guidance, technical support, instruction, and encouragement.

Once students participate in the Project, their involvement never really ends. It is a continuing educational experience. The talents, skills, and teamwork derived from creating, building, and flying an aircraft stay with them for life.

It is inspiring to see the aircraft you have built become alive and airborne in its first test flight. Many students have been reawakened to their potential in life. What began as a realization of the potential of using an airplane as an educational tool, became much more than that. It is a celebration of one of mankind's greatest adventures and accomplishments—the freedom of personal flight. ■

Project Mercury

Before it Became Project Mercury

Standing in NASM's *Milestones of Flight* gallery and looking at the *Friendship 7* capsule in which John Glenn became the first U.S. astronaut in orbit, one seldom asks "Why does this spacecraft look the way it does?" Yet there was nothing inevitable about the design of the first U.S. manned spacecraft; its characteristics were a matter of engineering choice, and the engineer most responsible for the Mercury capsule was Dr. Maxime Faget. Dr. Faget worked with NASA and its predecessor organization, the National Advisory Committee for Aeronautics, through most of his professional career. From 1962-1982, he was director of Engineering and Development at NASA's Johnson Space Center in Houston.

Dr. Maxime A. Faget
Vice President, New Systems Development
Eagle Engineering, Inc.

In early October 1957, the National Advisory Committee for Aeronautics (NACA) called together a group of experts from its several laboratories for a special meeting to discuss the feasibility and possible performance characteristics of a new high-speed research airplane. It would be the successor to the X-15 which, at that time, was in its initial stages of construction. Such an airplane would fly at least twice as fast as the X-15, thus representing the third generation of high speed research airplanes. The first generation was the X-1 and similar research airplanes; these were designed to explore the transonic speed regime. The thought for the third generation was that speeds in the neighborhood of Mach 12 and above might be desirable for military aircraft, primarily a "Glide Bomber," which at that time was receiving a great deal of attention within the Air Force.

Sputnik was launched on the second day of this meeting creating an atmosphere of both chaos and excitement:



John Glenn's *Friendship 7* capsule, in NASM's *Milestones of Flight* gallery, is included in a tour for school children. These tours are conducted by the Museum's docents.

chaos because many ideas and research programs of current interest would soon be challenged, and excitement because the participants recognized that the development of artificial satellites and space exploration might easily project the world into a new era, one in which there were numerous research and development opportunities in fields in which they could play significant roles. Even at that very beginning of the Space Age, NACA personnel realized that the role of their agency would be changing dramatically.

NACA did indeed change. In fact, it became the core of NASA, which was organized during the following October. NACA had been created by an Act of Congress during World War I, when it was realized how woefully behind in aircraft research the U.S. was relative to European countries, which had been engaged in research to support military and commercial aircraft development. From its inception in 1915, NACA was a highly professional research agency

with a very low political profile. It carried out its programs with modest appropriations and tried, almost to the point of obsession, to avoid any publicity. NACA had a strong and enduring relationship with the armed services, primarily the Army Air Corps (later the USAF) and the Naval Air Corps. After World War II, the armed services represented the biggest client for NACA's research; in fact, NACA depended quite heavily on DOD support to fund a portion of its programs and to justify its appropriations before Congress.

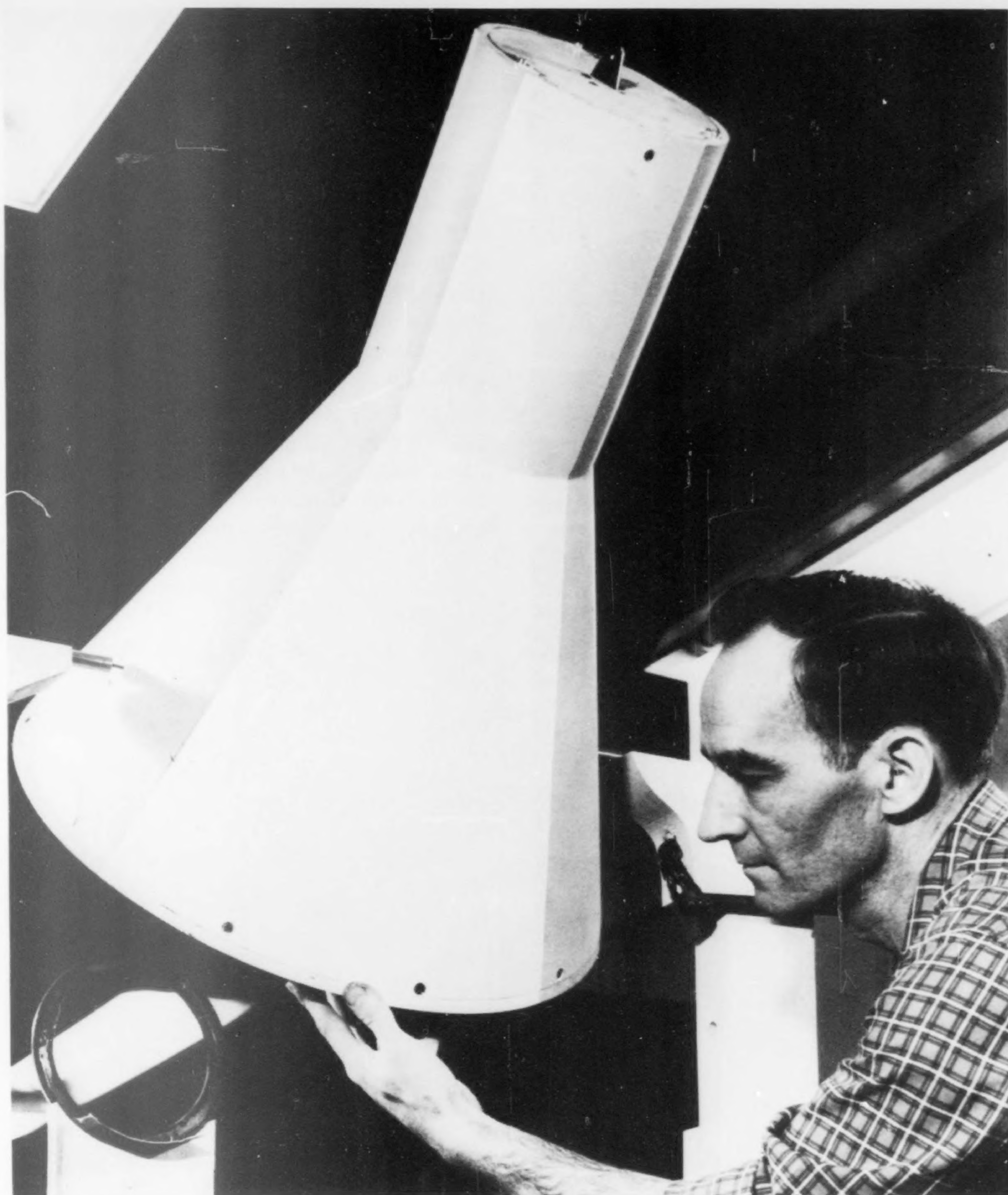
NACA operated primarily out of three research centers: Langley in Hampton, Virginia; Lewis in Cleveland, Ohio; and Ames in Sunnyvale, California. At Langley the Pilotless Aircraft Research Division (PARC), which was directed by Dr. Robert R. Gilruth, was particularly involved in the NACA transition to the space age. Since World War II, PARC had used surplus military solid rockets to propel flight research vehicles that investigated phenomenon

of aerodynamic heating, transonic flow effects, stability, control, structures, and virtually every aerodynamic phenomena associated with flight.

Prior to Sputnik, the aeronautical community assumed that manned orbital flight would indeed be achieved, but only when airplanes had been developed to go about 29,000 km/hr (18,000 mph.). The October 1957 meeting was considered a logical step along this path. Both the power to accelerate to orbital speeds and an appropriate aerodynamic configuration appeared to be critical design requirements for achieving orbital flight.

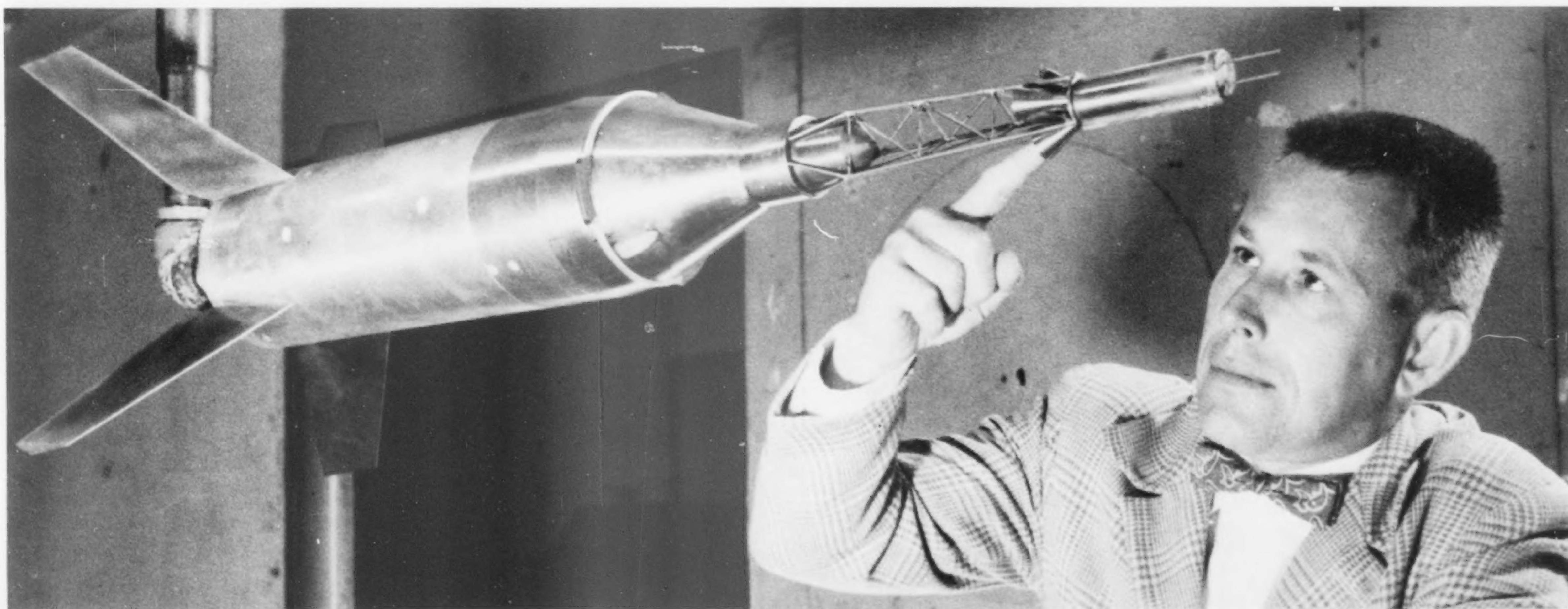
The flight of Sputnik dramatically shifted the focus to an alternate approach. Rocket-propelled acceleration along a trajectory that was mostly outside the atmosphere (thereby avoiding aerodynamic effects) suddenly became a much more realistic way of achieving the goal of orbital flight. Once in orbit, the duration and distance of the flight could be as long as desired, with the flight terminated by a maneuver that would return the vehicle into the atmosphere.

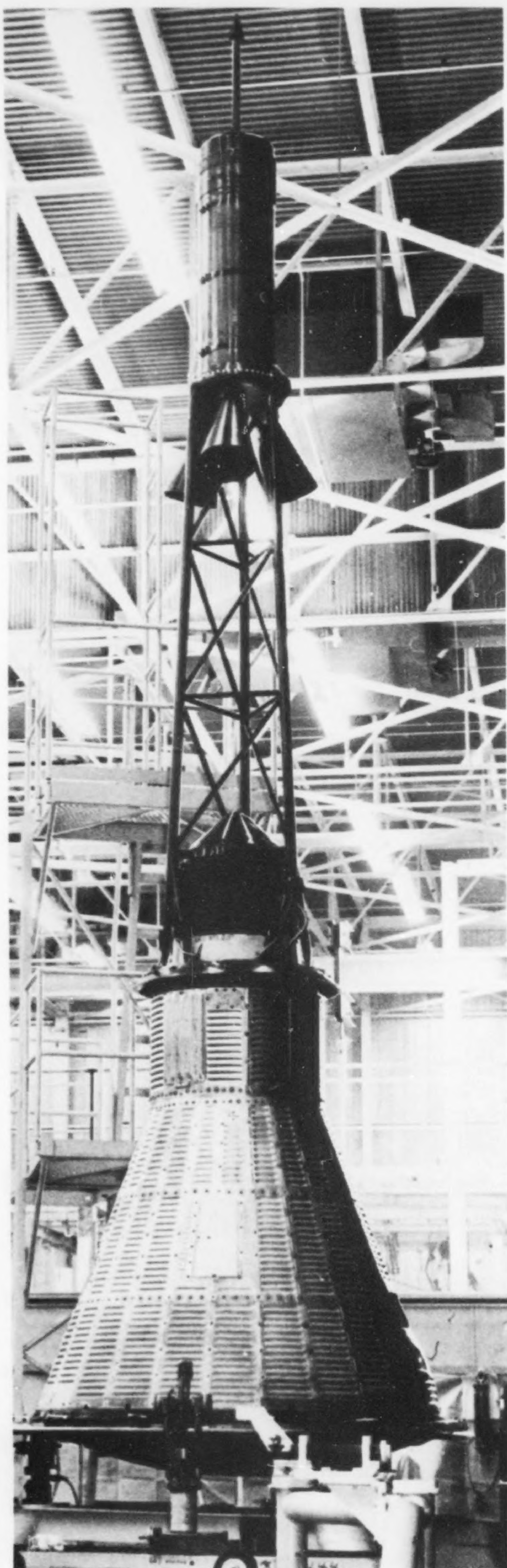
Dr. H. Julian Allen, who subsequently became Director of Ames, proposed a simple high-drag, non-lifting vehicle as the best means for initial manned space flights. There were others who were convinced that a lifting body would be a better choice, because a small amount of lift would allow maneuvering during the descent and thereby alleviate the high gravity (G) loads on the crew and allow navigation to a desired landing point. However, most of those who considered the problems of spaceflight still favored an airplane-like configuration, much along the lines of the very high-speed research aircraft that was under consideration at the meeting. The possibilities of manned orbital flight intrigued me, and I particularly liked the idea that it could be done soon with a simple ballistic entry.



A Langley technician conducts a center of pressure test with a large-scale stability test model of one of the earlier designs of the Mercury capsule.

A Langley employee works with the Little Joe rocket (left), which was used to test the escape tower. A failure of the Atlas during ascent in the atmosphere would cause an explosion that was almost certain to destroy anything in the immediate vicinity. The solution was to mount a tractor rocket (escape tower) on a truss to the nose of the capsule. Given a one-second warning, this escape tower could put the capsule a safe distance from an explosion.



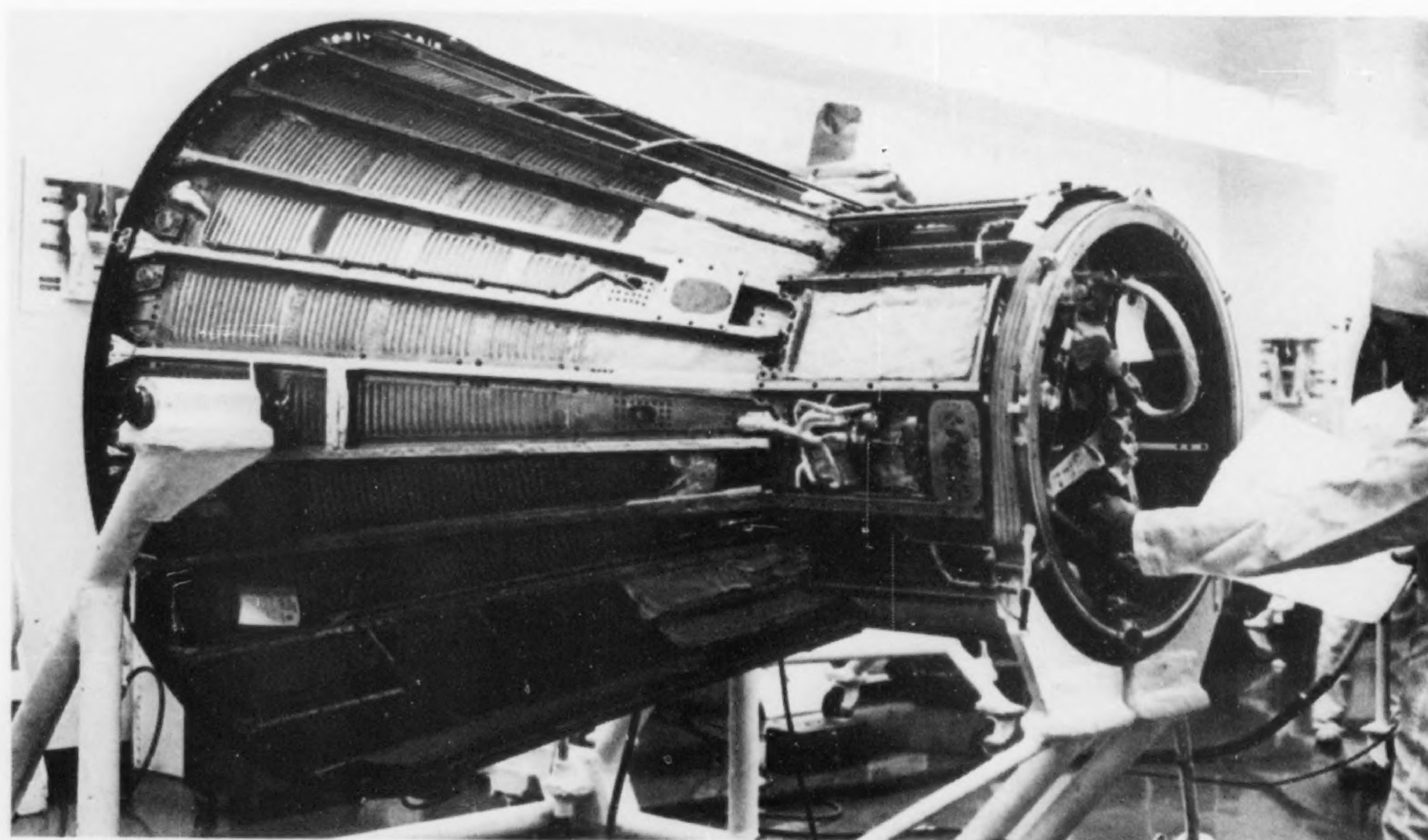


Upon return to Langley, I organized a small ad hoc group to study the possibilities of manned orbital flight using a simple space capsule. Analyses were made to investigate the atmospheric entry characteristics of both non-lifting and simple ballistic vehicles. Comparisons of flight paths and aerodynamic heating were made. We found that a non-lifting ballistic entry encountered significantly reduced heating but did so at the expense of much higher deceleration. Regardless of how shallow the entry might be, up to 8 Gs would be encountered during an entry without lift. This was because as the capsule lost its velocity during the early part of entry, its flight path steepened. Consequently, it would encounter the higher density atmosphere at a much more rapid rate than would a lifting vehicle, which could maintain a higher altitude while decelerating.

The lifting reentry, however, was subject to skipping instability in its flight path. This skipping tendency would require special navigation and flight control techniques during entry. The ballistic vehicle would definitely be simpler to develop. Its main problem was the high "G" loads, but examination of aeromedical data, primarily from German sources, indicated that the expected deceleration profile should be tolerable for healthy young adults supported in a supine position.

Left: The first of the Project Mercury Space Capsules instrumented for escape system tests. The capsule is shown at the McDonnell-Douglas Aircraft plant in St. Louis before being delivered to NASA at Wallops Station, Va. The pylon atop the capsule incorporates the escape system.

Below: Side view of the Mercury capsule during fabrication. Although a group of NACA experts met in 1957 to discuss a new high-speed research airplane that would succeed the X-15, as events unfolded, the conference led to the design of our first spacecraft, Mercury.



Having decided upon a ballistic entry, we did not find it too difficult to work out the actual shape of the capsule. To begin with, heating data had already been obtained on a series of blunt-nosed cylinders varying from a perfectly flat nose to a cylinder tipped with a hemisphere; in between noses had spherical surfaces with the radii varying from that of the cylinder to infinity.

Analysis of both the drag and the heating rate on this set of nose shapes indicated that a nose radius approximately three times the radius of the cylinder would be optimum. In this case minimum heat would be transmitted to the heat shield during reentry. We discovered this particular nose shape also had a nearly uniform heating rate over the entire spherical surface. By contrast, with a hemispherical nose, the heating would be greatest right in the center; with a flat nose, the heating would be greatest at the perimeter. Thus, we had discovered not only the most efficient heat shield but also the one that could most easily be manufactured since it could be designed for uniform heating. The other end, or afterbody, of the capsule was made conical to minimize heating on its surface and to provide an enclosure of sufficient volume to house the crew and equipment of the orbiting capsule.

Although the resulting shape was statically stable, it lacked dynamic stability. This meant that during descent it would properly turn into the wind; however, its attitude would oscillate. The magnitude of oscillation would begin increasing during the final stages of descent resulting in an uncontrolled tumble prior to reaching the altitude for parachute deployment. This clearly was not a desirable situation for a manned vehicle.

We planned to equip the capsule with attitude control jets that would dampen and prevent this oscillation. However, we knew that total reliance on an active system could be avoided if the stability could be improved. Therefore, we tested a series of dynamic models, each with the chosen heat shield but with successively longer conical afterbodies. The tests were carried out in the Langley Spin Tunnel, which was a vertical tunnel with controllable air velocity. Thus an untethered model placed in the tunnel could be made to float in the test section when the tunnel's wind velocity produced sufficient drag to overcome the model's weight. Results of these tests indicated that an afterbody length of approximately one and one-half times the diameter would be marginally stable. In this case the model would rock back and forth with an amplitude of about 45 degrees but would not tumble. Such a motion might not be comfortable, but it would only be encountered

in the unlikely event that the attitude control jets failed. However, to be certain that this motion would not be debilitating to the crew, we built a crude mockup of the capsule with a couch in it. Tests were made by hanging the mockup, occupied by a test subject, on a cable of proper length to produce the expected amplitude and frequency that would be encountered during flight.

All of the above work was done by a handful of people in just three or four months. NACA had no approved application in mind. However, it was felt that manned space flight was soon to be a national goal, and keen interest was displayed by several Langley managers. It was assumed that if such a project were to materialize, it would be carried out by one of the armed services, most probably the USAF.

During the spring of 1958, the Eisenhower Administration decided that NACA would indeed become the starting nucleus of the new space agency. Both the Lewis and Langley laboratories were requested to provide special support teams to NACA Headquarters to facilitate the transition. The primary emphasis was to identify suitable programs and organizations for the new agency. My role related primarily to possible manned space flight programs. Since the Army, Navy, and Air Force all had proposed manned space flight projects, DOD had requested its Advanced Research Projects Agency (ARPA) to evaluate their technical merit. Assignment of manned space flight responsibility either to the military or to the civilian program was still an unresolved issue. NACA and ARPA set up a joint committee to evaluate all manned space flight proposals. During this period it became apparent that the Atlas intercontinental ballistic missile, which was a leading contender for the launch vehicle for initial manned orbital missions, could launch as much as 907 kg (2000 lb.) into orbit. Before then, we at NACA had assumed that the Atlas would require another stage to lift even the smallest manned spacecraft into orbit. Getting sufficient performance from the "bare Atlas" meant that costly and time-consuming development of upper stages could be avoided. It also represented a big step toward adoption of the simple ballistic capsule, since any other approach would not be feasible with the weight constraint of the "bare Atlas."

Two other significant design problems remained, both associated with the serious concern for safety during launch. The Atlas, like other ballistic missiles at that time, was not expected to be more than 80 percent reliable. If the loss of the Atlas would in turn destroy the capsule, it was obvious that it was not safe for manned flight. A failure of the Atlas during ascent in the atmosphere would result in an explosion that

was almost certain to destroy anything in the immediate vicinity. Our solution was to mount a tractor rocket on a truss to the nose of the capsule. This "escape tower" was capable of almost 20 "Gs" of acceleration. We determined that given a one-second warning, this escape tower could put the capsule a safe distance from an explosion. When all the Atlas failure modes were finally analyzed, we estimated that impending failures could reliably be sensed at least one and one-half seconds prior to a possible explosion. The "escape tower" could also carry the capsule to sufficient altitude to deploy its parachute if the



The historic launch of the Mercury-Redstone III on May 5, 1961, placed America's first man in space, Alan B. Shepard Jr. It also inspired Kennedy to commit our country to an active space program that enabled us to land on the Moon eight years later.

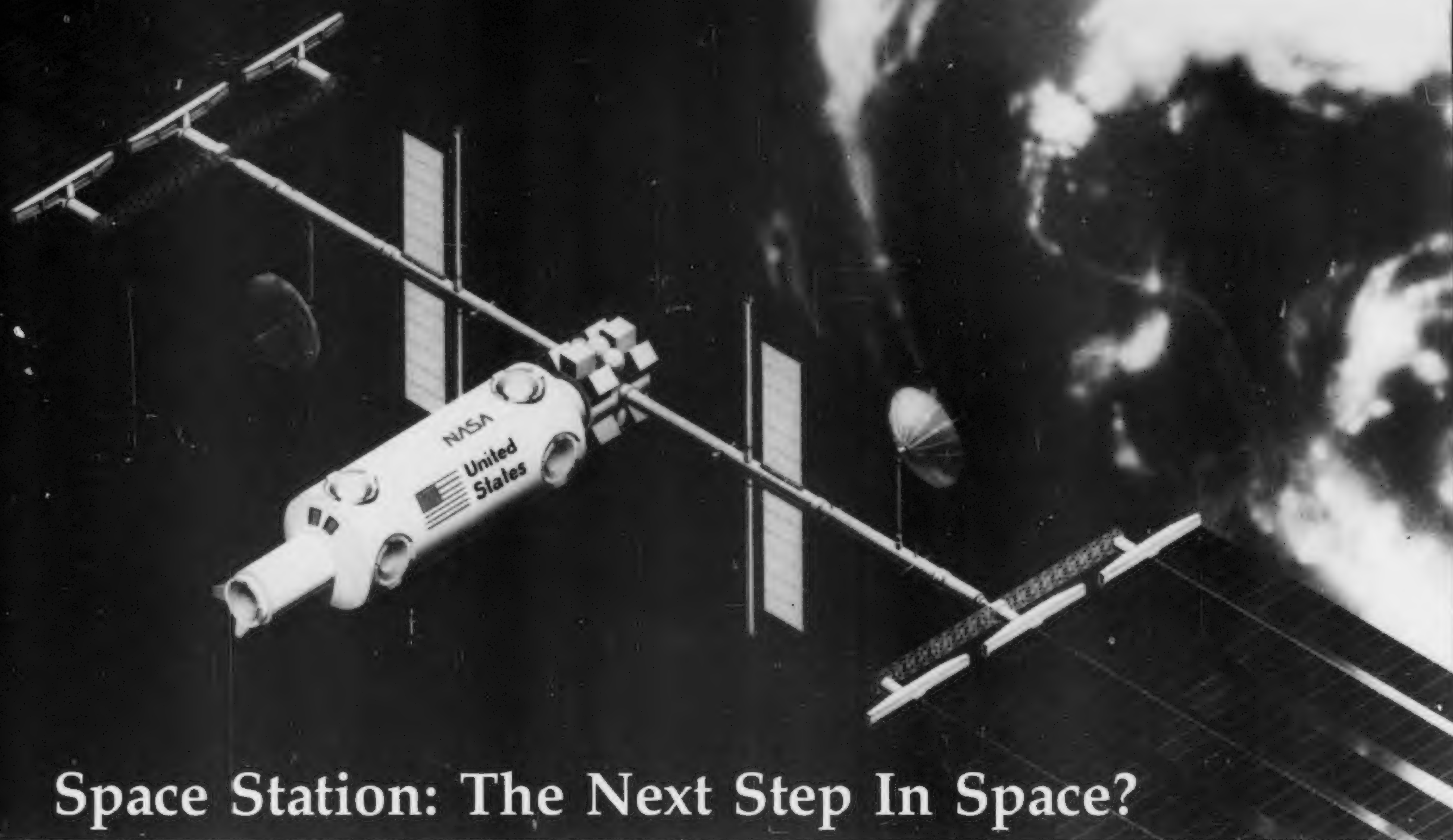
emergency took place before lift-off.

A failure of the Atlas at later times, when it was above the atmosphere, represented a different hazard. Such a failure was not expected to result in an explosion; however, the capsule after separation would be left on an undesirable trajectory, the worst case occurring at about 75 percent of orbital velocity. In this case, the capsule, after separation, would fall a considerable distance before it entered the atmosphere. During the free fall period, sufficient vertical velocity would accumulate to make the flight path significantly steeper than the planned grazing reentry at the termination of a normal orbital flight. The consequence would be that a maximum deceleration of 19 G could be expected.

We had already decided to use a molded, form-fitting couch to support the crew in the desired supine position against G loads during reentry. Both acceleration during launch and deceleration during entry were properly accommodated by positioning the capsule's conical end "upwards" on the launch vehicle and by making the reentry maneuver with the blunt end forward.

Couches for tests with human subjects in the Naval Air Development Center (NADC) centrifuge at Johnsville, Pa., were prepared. These tests were planned for loads only up to 8 G, a regime that had been previously explored by the Germans. The discovery that G levels more than twice this value might be encountered during an abort became a major concern. Providentially, a hero stepped forward. Carter Collins, a member of the NADC staff and himself a test subject, had become greatly interested in our project and wanted to try the couch at G levels higher than 8. He was told that if he could successfully withstand a 20 entry time history, we would be forever grateful. The next afternoon Collins made a series of runs progressing from 10 G to 20 G in two to three G increments. Several weeks later, in a test to explore the limit of human tolerance more daringly, he rode the centrifuge at 25 G! At that time, it was still several months before the official birth of NASA, the authorization of the initial manned space flight program, and the choosing of the name "Mercury." But with this series of tests, the critical design problems for what would soon become the Mercury capsule had been essentially solved. ■

In any team effort certain individuals stand out. So it was during the period described in this article. Without the initiative and diligence of Woody Blanchard, Jack Heberlig, Jack Garland, Jim Buglia, Jerry Hammack, Caldwell Johnson, Chuck Mathews, Andy Meyer, Betsy Magin, and Bill Stoney, the Mercury Program, as we know it today, may not have been.



Space Station: The Next Step In Space?

Figure 1—This artist's concept illustrates one design approach of the Space Operations Center (SOC) in an early phase of evolutionary growth. With the command module in place, the SOC is now capable of command, control, etc.

Next year NASA will celebrate its 25th anniversary. As it starts this second quarter century in space, NASA believes its next major undertaking should be the development of a manned space station. Philip Culbertson directs NASA's efforts to formulate policy, strategy, and planning of a facility to provide a "permanent presence" in space. In this article he explains the basis for NASA's position regarding a manned space station and the role that it will play in the national space program.

Philip E. Culbertson
Associate Deputy Administrator
NASA

As we look to the 1990s and beyond, it is difficult to judge the directions this nation and others will move toward in their exploitation of space. Although little is known about Soviet planning, recent statements indicate that the Soviets intend to vigorously pursue their already strong manned program. This would take place through continued occupancy of their Salyut class space station and, possibly, by launching and occupying a significantly larger station within the next two to three years. These plans appear to support other statements about the USSR developing a new launch vehicle with a capability exceeding that of the

Saturn V, the immense U.S. rocket used for the Apollo program. It is clear that developments and commitments of this magnitude have strong national security as well as civil implications. In addition to its manned program the USSR continues an impressive space science program, historically concentrating on the inner planets. The development of an increased launch capability, however, will provide an opportunity for expanding their research to the outer solar system.

The European Space Agency, representing the space-faring nations of western Europe, continues to move forward, both in the development and operation of satellites and in the development and commercial marketing of the expendable launch vehicle, Ariane. In addition, individual nations in Europe are supporting national programs with an increasing emphasis on commercial exploitation of space opportunities. Japan's national program includes both spacecraft and launch vehicles, as does the Chinese program. India has a launch vehicle under development. Many other nations, recognizing the growing dependence of international communications on space-based transponders, are planning their own communications satellites.

A Second United States Space Station

It is in this environment of growing international investment in space that NASA has initiated a study of the potential uses of a space station and of the extent to which it could contribute to the effectiveness and efficiency of space operations. The basic rationale for the station is that it will bridge the gap between the relatively short time on-orbit provided by the Shuttle and the extended orbital capability of unmanned spacecraft. This would establish new opportunities for space-based research, observation, fabrication, maintenance, and support of unmanned facilities and laboratories. It would also provide for space-based maintenance and operation of the propulsion stages required to move beyond low-Earth orbit. The current NASA study is building on the body of data obtained during the three manned missions to the first U.S. space station, Skylab, which were carried out in 1973 and 1974, and on projections of U.S. space activity anticipated for the 1990s. The results of these, and similar studies under way in Europe, Canada, and Japan, will be analyzed to establish space station mission requirements and system characteristics and capabilities. These, in turn, will form the basis for preliminary design studies as well as an

understanding of likely development and operations costs and a probable overall program schedule. These data will provide the option for accepting—or rejecting—a national commitment to begin space station development.

At the outset of the current studies a set of general conditions was established to bound the investigation. The space station was to be modular in design, so that each of its elements could be delivered to orbit by the Shuttle. It was to provide for evolutionary growth by adding new modules to increase its size or capability or by upgrading of system technology. Its lifetime was undefined, although realistically a lifetime of 20 to 30 years would seem to be an appropriate design target. Particular efforts would be placed on simplifying the interactions between the station itself, prospective users, and ground support requirements. It was further assumed that the initial launch would be in 1990 or 1991.

Early study results have identified five categories of station operations. The first is its use as a laboratory, exploiting its unique zero-g (gravity) environment. Ideally suited for areas of biological research requiring man's presence as an experimenter and observer (as well as, on occasion, an experimental subject), it would also support experimental testing and certification of components and systems that would later be incorporated into manned, or unmanned, operational spacecraft.

The second broad category of uses includes those activities that capitalize on the location of the space station 322-563 km (200-350 mi.) above Earth, circling it once each hour and a half, covering a broad band north and south of the equator. From this vantage point the crew could select areas on which to focus a range of observing instruments sensitive to different spectral frequencies in order to highlight particular terrestrial or atmospheric features and characteristics under study. It may also be possible to use the human ability to integrate data from many sources and to selectively reject that which is unimportant to increase efficiency in the collection of observational data.

The third type of space station utilization is based on providing manned support to nearby unmanned spacecraft. Flying in the same orbit as a large astronomical facility such as the space telescope, but separated from it, the space station could serve as a maintenance base. The space telescope, because of its requirement for extreme stability and contaminant free environment during observing periods, is being built as an unmanned spacecraft. Routine maintenance, instrument exchange, repair, and resupply of expendables is now planned to be provided by Shuttle visits. A nearby space station,

however, could provide a ready supply of "spare" parts and tools, and uncouple maintenance schedules and activities from Shuttle operational and stay time limitations. Other visits to unmanned spacecraft could involve resupply of raw materials for space-based materials processing factories and removal of their finished products.

The space station could also serve as a construction base supporting the fabrication and assembly of systems too large to be carried in the Shuttle cargo bay. Very large solar energy collectors, high-gain antennas, and even large optical systems will, in the quarter century ahead, outgrow the Shuttle. Some system growth will be possible by assembly using the Shuttle as the construction platform. The rather limited Shuttle orbital stay time of 10-15 days however will establish an upper limit to the extent of support of this type. The space station would greatly extend the capabilities for on-orbit construction.

Finally, the space station could offer an opportunity to base in space a propulsive stage or transfer vehicle to move spacecraft from low orbit to higher orbits and beyond. Space basing in this way will allow the development of geosynchronous satellites significantly larger than is possible today. Having the propulsive stage remain in orbit would also avoid the need to transport it from

Earth into orbit time after time.

None of these ideas has been studied enough to show conclusively that it warrants being incorporated into the space station capabilities. Each, however, is being studied further and in greater detail to determine whether or not it should be reflected in system design.

Following further evaluation of these and other potential space station uses, NASA will examine specific design concepts to test whether a system can be built to accommodate all of the prospective uses and still comply with the general guidelines that have been established. Development and operations costs will, at that point, have a major impact as system choices are made.

Design Concepts

Figure 1 illustrates one design approach in an early phase of evolutionary growth. The first modular element taken to orbit by the Shuttle would have been the twin solar arrays, twin dish antennas, thermal radiators and the booms on which they are mounted, and the docking hub that includes the energy distribution systems and the flight control system. These systems would have been nested in the 18 m × 4.5 m (60 ft. × 15 ft.) Shuttle cargo bay. Once in orbit, the Shuttle crew would extend

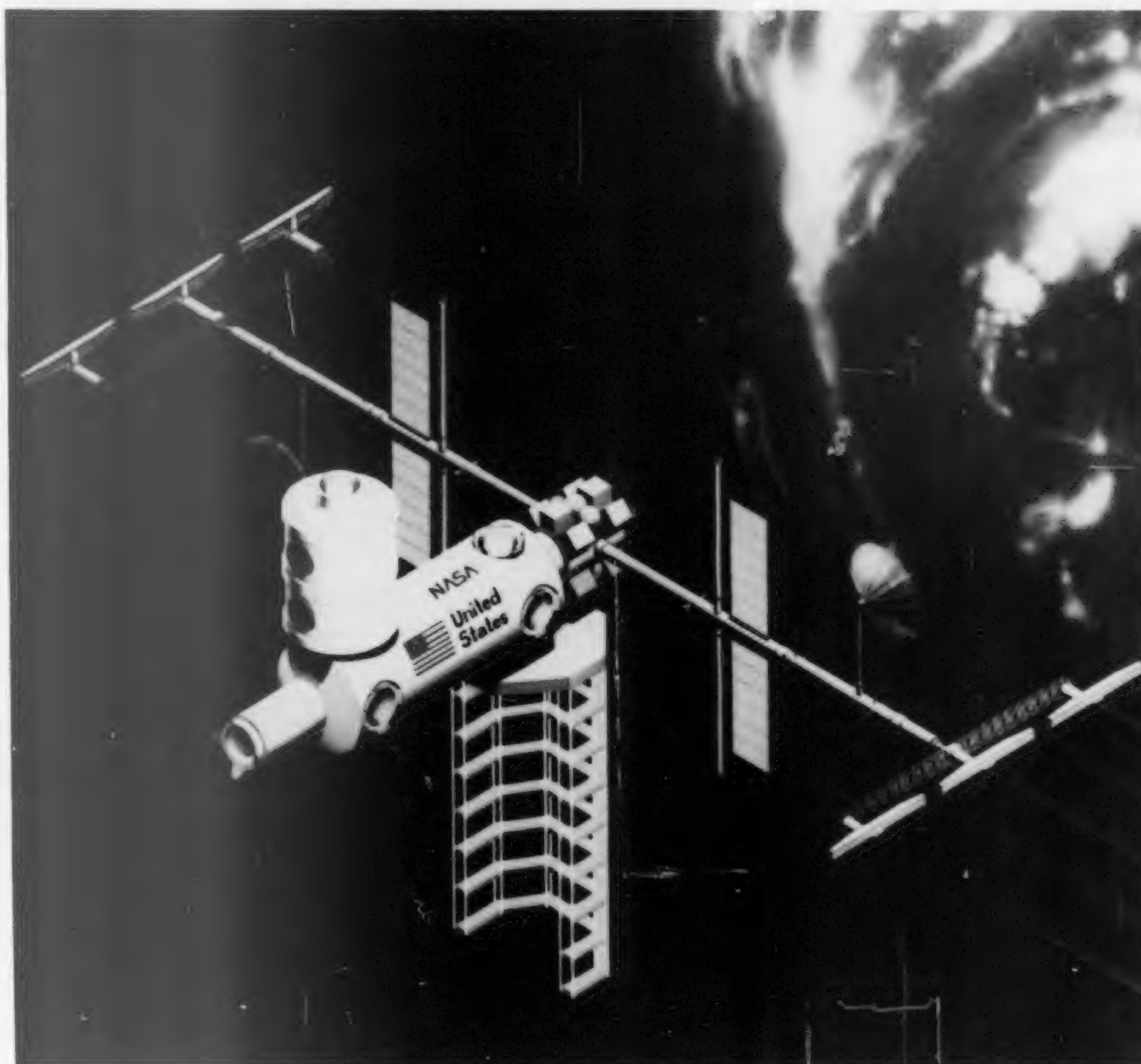


Figure 2—In this illustration, the Space Operations Center (SOC) is now capable of even more functions. A new pressurized laboratory has been added, perhaps equipped for a unique set of investigations. This completes Phase 1 of the operations center concept for a shuttle-serviced, permanently manned facility suggested by NASA's Johnson Space Center special study team.

and activate them so that the first module would be a self-sufficient free flying unmanned spacecraft. After an initial checkout period on orbit, a second Shuttle would be launched to deliver the second module, which would become manned—a cylindrical habitat approximately 4 m (14 ft.) in diameter and 15-17 m (50-55 ft.) long. This module, similar in size to a mobile home, would provide basic living accommodations for a crew of four: possibly a station manager, a technician, a scientist, and a physician. A small cylindrical air lock at the end of the habitat would permit entry into and egress from it and serve as a safe haven in which to wait for a Shuttle pickup if the main cabin were to become uninhabitable. The Shuttle crew would join the two modules and perform initial checkout prior to departure. Although this two-module station would be limited in capability, it would be placed in operation at this point, primarily serving as an orbital laboratory. Figure 2 shows the station as it might begin to evolve from this first step. In this illustration a new pressurized laboratory has been added, perhaps equipped for a unique set of investigations. It would be delivered by the Shuttle and attached to one of the docking ports in the initial habitat. An open beam structure is also shown attached at a second docking port. Although this particular structure is intended to support unpressurized experimental equipment, a similar one could be used

as a support for construction or as a berthing framework for unmanned spacecraft under repair. Other modules under consideration include a logistics transport canister for bulk cargo, consumables, tools, or spare parts; a hangar to house a space-based propulsive stage; tanks for storage of propellants delivered by the Shuttle on "space available" manifest; and a small tug to raise the decaying altitude of the station caused by the small atmospheric drag in a low-Earth orbit.

A space station designed using this modular approach provides much versatility by allowing experience at one stage of evolution to influence its function and configuration at a subsequent stage. This kind of approach has never been attempted in a space vehicle before, however, and will require a well thought out growth pattern if it is to be successful.

Figure 3 illustrates a system of space stations derived from a single basic design but deployed in two different orbits. One station in polar or Sun synchronous orbit is used as a manned observation platform and as support for unmanned spacecraft, such as Landsat, in a similar orbit. A second station, in a low inclination orbit, has evolved to a significantly more advanced configuration capable of supporting the assembly of a large antenna that will be subsequently boosted to geosynchronous orbit. It also has many manned modules and is providing support to the space

telescope and a long-duration unmanned materials processing facility derived from the original space station elements. A small propulsion module is used to ferry between the space station and the unmanned facilities. Later, growth could provide support to a space-based propulsion system to ferry between the Shuttle-compatible space station and geosynchronous orbit.

Our studies have just begun to develop a space station operations plan. We know from our Skylab experience that although some biomedical changes take place during a three-month mission, no long-term effects remain. The Soviet experience would indicate that missions can be extended up to six months with similar results. Early space station crew rotation will therefore probably be planned at intervals of from one to three months; this will provide medical data to guide plans for more extended missions. If the design follows the general outline described in this paper, operations would begin with a crew of three or four and grow as new modules with added habitability provisions are added. The Shuttle will transport crew members, logistic supplies, and new or replacement modules to and from the space station. The station will be planned to simultaneously support varied activities using short term specialists along with other crew members having more general responsibilities for more extended missions. Guest investigators will be transported to the station to use its facilities, much as astronomers use terrestrial observatories. Commercial industries will reimburse the station operator for the services they use and the transportation they require. Access to the space station by foreign users will be provided in a manner similar to that currently available for the Space Shuttle. These and other general guidelines are being used to develop operational concepts that will mature as NASA's ideas on the station evolve.

Whether the U.S. develops a space station is yet to be determined. It is apparent, however, that the space program at age 25 has matured and demonstrated its utility. The U.S. space program and those of other nations have expanded far beyond what most people considered to be possible in the late 1950s when the space age began. This expansion is providing a basis for both increased competition and cooperation, as the U.S. seeks to exploit this frontier for the unique attributes that it offers. The space station under study could provide a totally new dimension to space capability. With it man will no longer be an occasional visitor. We will remove the limitation of time from our space activities and add to them the dimensions of growth, providing new opportunities to exploit the unique characteristics of space for the benefit of mankind. ■

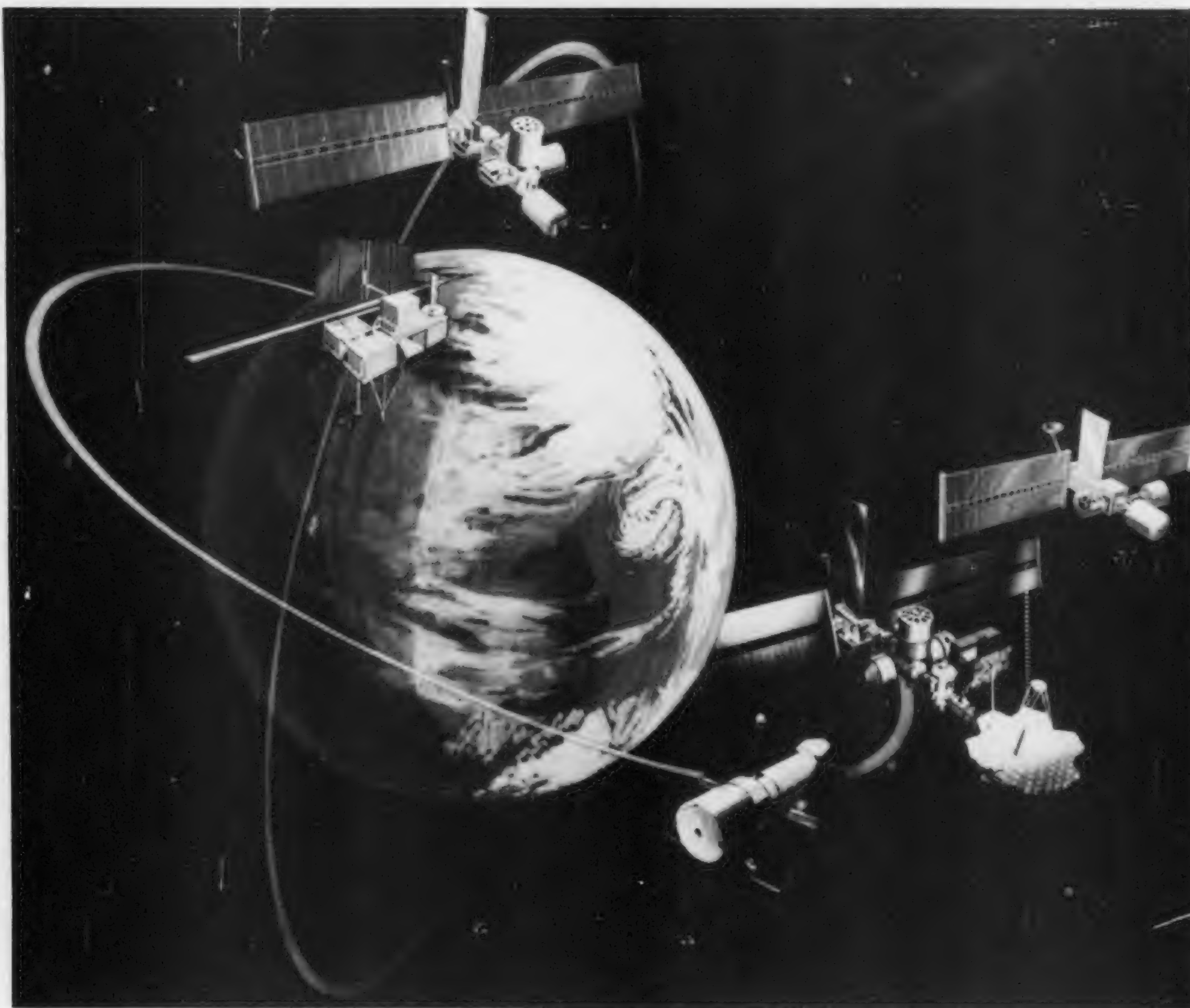
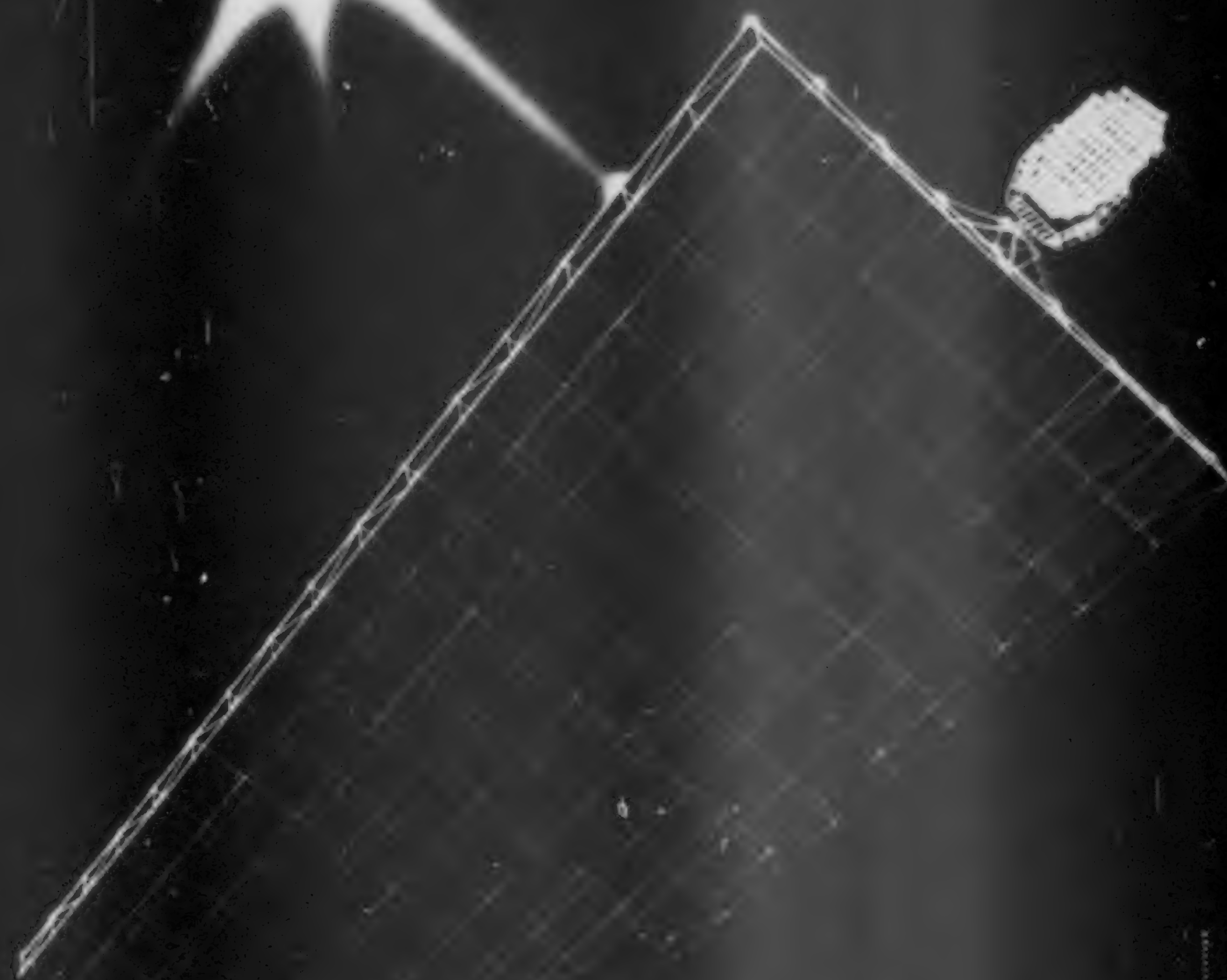


Figure 3—This illustration (not to scale) by the Marshall Space Flight Center is a space station concept that incorporates both high inclination and low inclination stations that service co-orbiting, unmanned scientific platforms. The unmanned element in polar orbit is a European-built platform dedicated to materials processing. In the equatorial orbital facility the "hangar" with an open door housing has an orbital transfer vehicle (OTV).



Energy From Space—A Goal For Space Industrialization

The Solar Power Satellite (SPS) is perhaps the most ambitious proposal to use space technology for human benefits. Over the past several years, there has been extensive study, discussion, debate, and criticism of the concept. In this article, the inventor of the SPS, Dr. Peter Glaser, makes an articulate argument in favor of giving SPS serious consideration.

Dr. Peter E. Glaser
Vice President
Arthur D. Little, Inc.

From an historical perspective, few scientific and technical achievements rank with the conquest of space as a turning point in human endeavors, but we are still too close to the dawn of the space age to fully comprehend the impact of extraterrestrial industrial activities and their implications for our future on Earth. These endeavors could be as significant in the 21st century as the industrial revolution was in the 19th century.

During the next several decades, technologies first developed for space exploration will make increasingly important contributions to the world economy. Space industrialization could provide valuable new services, products, and processes that take advantage of the low-gravity environment and the inexhaustible supply of materials and energy resources beyond the Earth's surface. However, at this early stage of space industrial development, with the exception of telecommunications and, to a limited extent, Earth observations, no new products or processes have been demonstrated and no hard data presented that can pass economic scrutiny as the basis for a commercial venture.

Space industrialization strategies will have to be based on projected long-term consequences, i.e., scenarios of various program options extending through the next 50 years. Such scenarios are necessary to focus near-term space missions in such a way as to ob-

The relationship of the Solar Power Satellite to the Sun and the Earth is shown in this artist's concept. Once a day the antenna will rotate with respect to the solar cell structure.

tain information on which to base succeeding missions. Generic space technologies can be developed to meet the requirements of varied missions, leading to step-by-step advances in the broad-based uses of space.

While space industrialization cannot meet every challenge facing society, the human prospect becomes much more encouraging when its potential benefits are taken into consideration. In sight is the technological capability to provide access to the limitless energy and material resources of the Solar System, which could sustain economic growth and advances in living standards of all people far into the future.

The availability of abundant energy without undesirable environmental consequences and at an acceptable cost is vital to future economic growth. There is a growing consensus that humanity will increasingly rely on renewable energy resources that have their origin in the energy radiated by the Sun.

Although there are many ways of reducing the magnitude of the energy supply challenges, only a few energy conversion methods have the potential to generate large amounts of power continuously. In addition to known methods based on coal and nuclear fuels and experimental attempts at ocean thermal energy conversion, there are two not-yet-demonstrated methods for continuous power generation: tapping the processes of nuclear fusion and obtaining energy from space.

The Solar Power Satellite Concept

A solar power satellite (SPS) could utilize various approaches, e.g., photovoltaic (direct conversion of the Sun's energy into electricity) and thermal electric (using the Sun's energy to generate heat, which is then transformed into electricity) to solar energy conversion. Photovoltaic conversion has been selected as a useful starting point for examining the feasibility of the SPS concept, because solar cells are already widely used in communication, Earth observation, and meteorological satellites, both in low Earth orbit (LEO) and in geosynchronous orbit (GEO). An added incentive for this selection has been the substantial progress being made in the development of advanced photovoltaic materials and increasing confidence in ultimately achieving significant cost reductions.

A solar power satellite would be placed in geosynchronous orbit; solar cell arrays would convert energy from the sun directly into electricity and then convert the electricity into microwaves. A transmitting antenna would precisely direct a microwave beam of very low power density from the SPS to one or more receiving antennas at desired locations on Earth. At the receiving antennas, the microwave energy would be safely and efficiently reconverted into electricity and then transmitted to users. An SPS system could consist of many orbiting satellites, each beaming power to one or more receiving antennas.

The SPS concept challenges a prevalent view that solar energy conversion cannot make a significant contribution to worldwide energy economies and demonstrates that there are no inherent limits to the development of energy resources in space. It represents an alternative direction for developing renewable energy resources and for engaging in sustainable human activities in space. Available energy from space could overcome many of the physical, societal, and institutional limitations to which future generations would be subjected by Earth's dwindling resources.

Providing large amounts of energy from space could change the belief that the planet Earth is a closed ecological system, with humanity destined to live

from generation to generation facing the threat of resource shortages and the resulting social upheavals. Extraterrestrial resources could satisfy some of the needs of the world's population in the 21st century. Without these resources, however, insistence for improvements in living standards, especially in the Third World, may be very difficult to meet. Even today, there is increasing confidence that, with known space technology, the resources of the Moon—oxygen, silicon, and aluminum—and possibly those in the asteroids could be the raw materials not only for the construction of the SPS but also for other orbital industrial complexes.

The SPS can be a major impetus for the development of space transportation systems and construction technologies to support many varied industrial uses of space with useful intermediate and long-term applications. SPS construction will require the presence of crews and the facilities to support them. An SPS would also benefit from the experience gained in many other space activities that will be undertaken in the next 20 years. Furthermore, the SPS presents an opportunity for peaceful cooperation among nations in space. And finally, it has the potential to reduce conflicts by eliminating the need for exploitation of energy resources at the expense of others; energy from space can be supplied on a global scale and thus be of benefit to all people.

Evolution of the SPS Concept

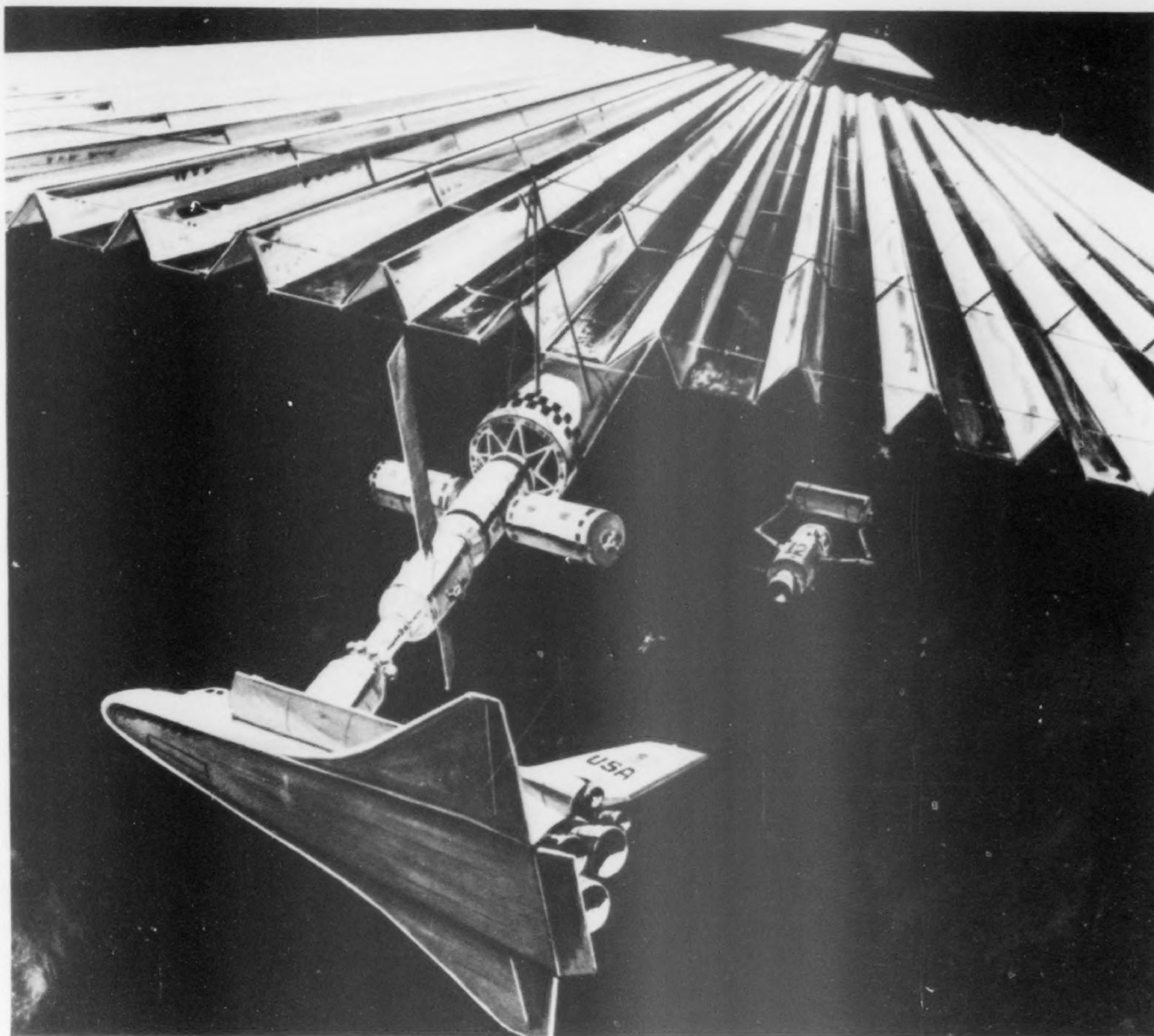
In 1972, the Solar Energy Panel of the National Science Foundation outlined a plan for an SPS research and development program. Also in that year, NASA started a program to evaluate the feasibility of the SPS concept. In that study, a reference system design was adopted to provide a power output of 5 million kW on Earth. In addition to investigating structural design and control requirements, microwave power transmission techniques were examined, and technological, environmental, and economic issues were identified. In 1975, extensive system definition studies were started. In 1976, the principal responsibility for the SPS program was transferred to the Energy Research and Development Administration (ERDA). On the basis of its own appraisal, ERDA recommended that a more complete evaluation be made. At about that time, ERDA was reorganized and absorbed within the new U.S. Department of Energy (DOE).

In 1977, DOE, working closely with NASA, started a three-year Concept Development and Evaluation Program (CDEP), with a budget of \$19 million, to develop an understanding of the technical feasibility, economical practicality, and societal and environmental acceptability of the SPS concept.

The CDEP provides a useful model for preliminary assessment of other energy conversion technologies. Although



The Solar Power Satellite is capable of beaming power to receiving antennas to supply the power needs of major population centers. The antenna can either be located on land or off-shore near such centers.



This artist's concept is one of several configurations of Space-Based Power Conversion Systems that was under study by the Marshall Space Flight Center and its contractors in 1976. A system like this could be placed in a geosynchronous orbit to collect pollution-free energy from the Sun and transmit it in the form of microwaves to receiving stations on Earth for conversion to electricity.

the depth of analysis was limited by the available funding, the studies supporting the program examined an unprecedented variety of issues that might influence development of the SPS. An explicit objective was to involve public interest groups in discussions about the SPS so that future decisions concerning the project could be based on a broad consensus rather than on narrowly defined expert opinion.

Since the conclusion of the CDEP, work related specifically to the SPS by U.S. Government agencies has not resumed, pending policy decisions about the future directions of the space program. There are, however, continuing studies, mostly funded by NASA, of technologies important to the SPS, including space transportation, large-scale construction in orbit, ion propulsion, space solar power conversion systems, and a permanent manned space station.

The SPS concept for utilizing energy from space for commercial purposes is directly applicable to peaceful purposes only. Proposals for beamed-energy weapons to disable satellites or missiles require a much higher energy level on their target than is required for power transmission. Furthermore, a power supply for weapons use must be designed for peak power generation and transient operations rather than for the continuous supply of energy that is in-

herent in the SPS concept.

The SPS concept can be designed to meet a wide range of commercial power generation requirements. One of the reasons for confidence in the technical feasibility of the SPS is that alternative technologies have been identified for nearly all components of the system. Most studies have been concerned with the SPS reference system that was evolved during CDEP to provide a common basis for many studies.

The SPS reference system is a conservative design based on known technologies that require limited development; it does not represent an optimized system. An operational SPS, which could be developed during the next 20 years, would use some of the many alternative technologies that already have been identified for advanced SPS designs and would thus be quite different from the SPS reference system. Just as one aircraft design does not meet all of the requirements of the air transportation industry, one SPS design will not suffice: varied SPS designs for different purposes will have to be developed.

While the SPS may be the most benign large-scale energy conversion technology yet conceived, many areas of potential environmental concern have been identified, including low level microwave biological effects, heating of the

ionosphere by the microwave beam, deposition of rocket engine exhaust products in the upper atmosphere, and interactions of ion engine propellants with the magnetosphere. Several of these effects are not well understood and a few may have long-term consequences. Therefore, steps to mitigate them will have to be explored. No environmental effects have been identified that preclude continued consideration of the SPS.

The Congressional Office of Technology Assessment indicated that, when operational, the SPS can be an economically attractive option for power generation. However, for most advanced technologies, e.g., fusion and the SPS, uncertainties in the projections of costs for up to several decades considerably exceed the cost differential that, in practice, will determine their relative competitiveness. Therefore, both the SPS and fusion are promising technologies, but further research is needed to provide data for economic analyses to justify decisions about their development and deployment.

The SPS has the potential to provide an economically viable and environmentally and socially acceptable option for power generation on a scale substantial enough to meet a significant portion of future world energy demands. The concept is based on the extension of known technologies and on further development of an effective space transportation system. There are no foreseeable technical impediments to the development of the SPS concept.

Conclusion

Modern civilization has successfully unlocked the frontier of space, a frontier that promises to extend human activities beyond the confines of the Earth's surface, opening up new opportunities that today can be perceived only in broad outlines. Space industrialization brings new options within reach and broadens the limits constraining society.

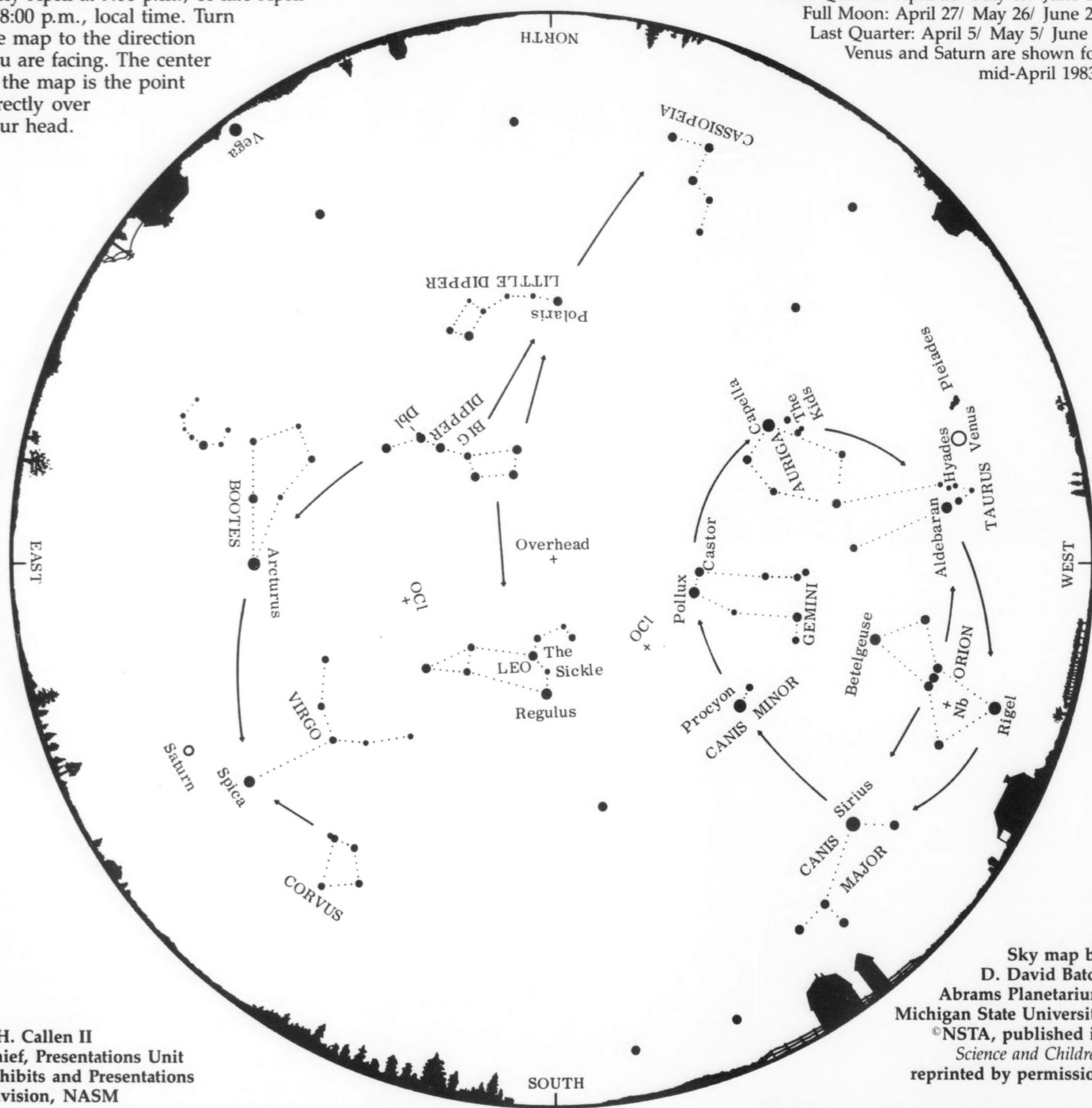
Development of the most effective SPS represents significant challenges that must be met realistically. However, it is as inappropriate now to discount the SPS as a major option for the 21st century as it was for American astronomer Simon Newcomb to state in 1906 that "the demonstration that no possible combination of known substances, known forms of machinery and known forms of force can be united in a practical machine by which man shall fly long distances through the air seems to the writer as complete as it is possible for the demonstration of any physical fact to be." Human imagination and creativity are the essential major ingredients for the successful implementation of the SPS concept. ■

Sky Map Spring 1983

This circle represents the night sky as it appears in late March at 10:00 p.m., early April at 9:00 p.m., or late April at 8:00 p.m., local time. Turn the map to the direction you are facing. The center of the map is the point directly over your head.

Phases of the Moon

New Moon: April 13/ May 12/ June 11
First Quarter: April 20/ May 19/ June 17
Full Moon: April 27/ May 26/ June 25
Last Quarter: April 5/ May 5/ June 3
Venus and Saturn are shown for mid-April 1983.



T.H. Callen II
Chief, Presentations Unit
Exhibits and Presentations
Division, NASM

Sky map by
D. David Batch
Abrams Planetarium
Michigan State University
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Science and Children
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Spring's skies blossom with clusters of beauty like the earthly flowers scattered below them, ranging from the naked-eye setting Pleiades and Hyades in Taurus to the rising, telescopic swarm of galaxies between Virgo and Leo. Between the Lion and Gemini, the Twins, is a small "+" marked OC1 (open cluster), the "Bee Hive" in Cancer, the Crab. Known to amateur astronomers as M-44 (from Messier's list of famous objects), this coarse association of stars is visible to the naked eye at apparent magnitude (m) +3.7. About 590 light years away, this 400 million-year-old grouping contains about 358 stars, the

faintest being about $m = +18$, over 63,000 times fainter than what the human eye can see.

The ancient Greeks called it "Praesepe," which means "Manger," or "Crib" (the kind that farmers use to feed animals). Two stars flanking the cluster, known as the "Aselli," represent two donkeys.

The Greeks also believed that they could forecast the weather by being able to see this star cluster. Both Tyrtæus Theophrastus (300 B.C.), the first botanist-author, and Aratos (270 B.C.), the astronomical poet, mentioned that the Praesepe's decrease in brightness indi-

cated approaching condensation of the atmosphere that would lead to rain. Even the two donkeys feeding at the Manger get involved as Aratos writes in his *Prognostica*, "A murky Manger with both stars Shining unaltered is a sign of rain. If while the northern Ass is dimmed By vaporous shroud, he of the south gleam radiant, Expect a south wind: the vaporous shroud and radiance Exchanging stars harbinger Boreas."

Your class might want to compare this method with that of the local weather forecaster to see who gets the greater percentage of accurate predictions.

Books from NASM Authors

Bringing Aerodynamics to America
by Paul A. Hanle. 184 pages, illustrated. MIT Press. \$20.00.

Bringing Aerodynamics to America provides an analysis of some of the major German scientists' personalities and their interactions, the institutions that nurtured them and that they developed, and the content of the theories that established their reputations in aerodynamics. It also describes the efforts to bring von Karman to Pasadena to set up a center for the study of theoretical aerodynamics based on the Göttingen model.

The Space Shuttle Operator's Manual
by Kerry Mark Jöels, David Larkin, and Gregory P. Kennedy. 160 pages, illustrated. Ballantine Books. \$22.50 hardcover, \$9.95 paperback.

This is what you would find in the glove compartment when you buy your space shuttle or are assigned for your flight. It is a guide in six sections: from Earth to orbit, living and working in space, emergency procedures, and space shuttle missions. *The Space Shuttle Operator's Manual* provides information from the astronaut's point of view, covering all aspects of the flight for the would-be crew member.

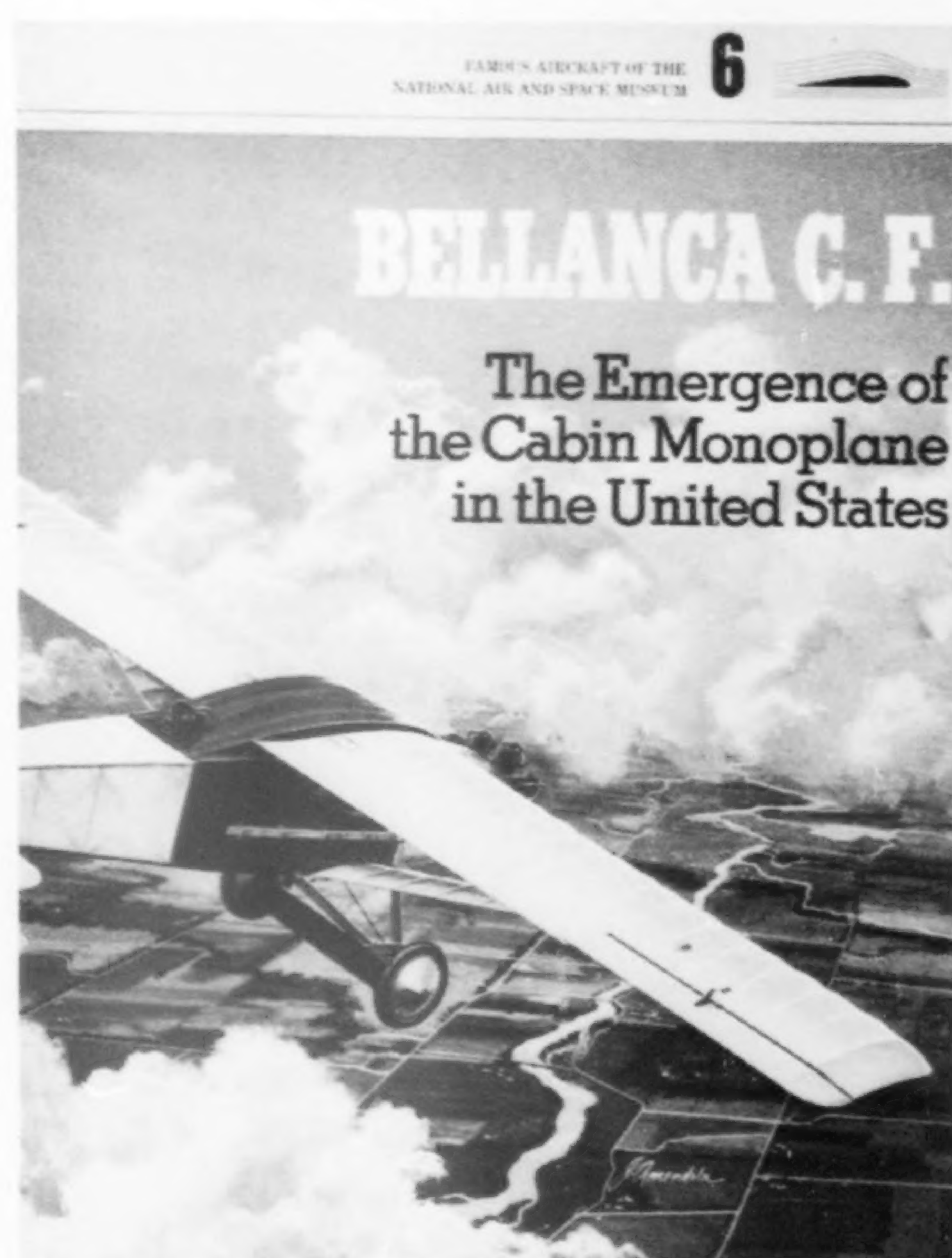
Black Wings: The American Black in Aviation
by Von Hardesty and Dominick Pisano. 80 pages, illustrated. Smithsonian Institution Press.

This book is a narrative and pictorial history of the American black in aviation from the entry of blacks into American aviation in the 1920s and 1930s, through the participation of black air personnel in World War II, to the present day role of blacks in the aviation and aerospace industries. Containing approximately 200 photographs, many unusual and previously unpublished, *Black Wings: The American Black in Aviation* also includes sidebars on prominent figures, anecdotal material on personal recollections of key figures, and a short bibliography. This book expands on the theme of the exhibit by the same name, which is on display at NASM, and will be published to coincide with a symposium on the subject to be held on February 25, 1983, at the Museum.



Bellanca C.F.: The Emergence of the Cabin Monoplane in the United States
by Jay P. Spenser. 95 pages, illustrated. Smithsonian Institution Press. \$7.95 paperback; \$1.75 postage and handling.

This book is one of the volumes in the Famous Aircraft of the NASM series that deals with an historic airplane in the Museum's collection. Each book covers the background and history of the plane in an illustrated format and describes, in detail, its restoration. The Bellanca C.F. marked the emergence of the first successful line of cabin monoplanes in the U.S. Designed and built by Giuseppe M. Bellanca, it led directly to the famous Bellancas that spanned the globe and significantly advanced commercial aviation. The C.F. was the most efficient airplane in existence at the time of its first flight in 1922 and quickly attained an unbroken record of first-place wins at major air meets.



Stars and Planets Symposium

Washington, D.C.
August 22-24, 1983

NASM is sponsoring a 3-day event of speakers, activities, and demonstrations in modern astronomy. Sessions will draw upon the concepts and artifacts exhibited in both *Stars* and *Exploring the Planets* galleries. Program participants will be selected from secondary level physical science and math teachers and administrators such as science curriculum supervisors. Write for an application form, which must be completed by May 27, 1983, to:

Janet K. Wolfe
Education Services Division
National Air and Space Museum
Smithsonian Institution
Washington, D.C. 20560

The Third World Congress on Aerospace Education

Washington, D.C.
July 10-15, 1983

More than 400 members are estimated to attend the Congress in the Capitol City of the U.S., to be held at the Capitol Holiday Inn, one block from NASM. The keynote speaker will be Dr. Hans Mark, Deputy Administrator of NASA. There will be presentations from the European Space Agency, the International Air Transport Association, Aerospaciale, and many others. Structured tours are planned for NASM, the Goddard Space Flight Center, the Smithsonian, and the Capitol. More than 30 Aerospace related firms and agencies will be exhibiting. The Second World Aerospace Film Festival will be held with entries from around the world.

World Aerospace Education Organization International (WAEIO) Youth Art Show

Scheduled to open in Washington, D.C., on July 10, 1983, the art show's theme is "Aviation and Space Flight Serving Humanity." Artwork of all media will be accepted from contestants, age 9-17, worldwide. Fifty paintings and drawings will be displayed from July 10-August 19, 1983, in the lobby of the NASA/U.S. Dept. of Education Building.

Artwork will be judged by prominent aviation and space artists. Deadline for entries is May 30, 1983. For more information on the WAEIO art show and for details on how to enter, contact Curtis Graves, Chairman, WAEIO, 8004 16th St., N.W. Washington, D.C. 20012.

The art show is being held in conjunction with the Third World Congress on Aerospace Education. The aim of WAEIO is to promote, through international cooperation, the development of aerospace education of youth and to enlighten the public in aerospace knowledge.

Recorded Tours Now available at NASM

This new tour, in English, French, Spanish, German and Japanese, focuses on Museum highlights such as the Wright Brothers' 1903 Flyer; Lindbergh's *Spirit of St. Louis*; the Apollo 11 command module; and much more. The cost is \$2 for one person, \$3.50 for a couple; \$5 for families of four or more; and \$1.75 for senior citizens, students with I.D.s, and Smithsonian Associates. Group rates for student tours are available.

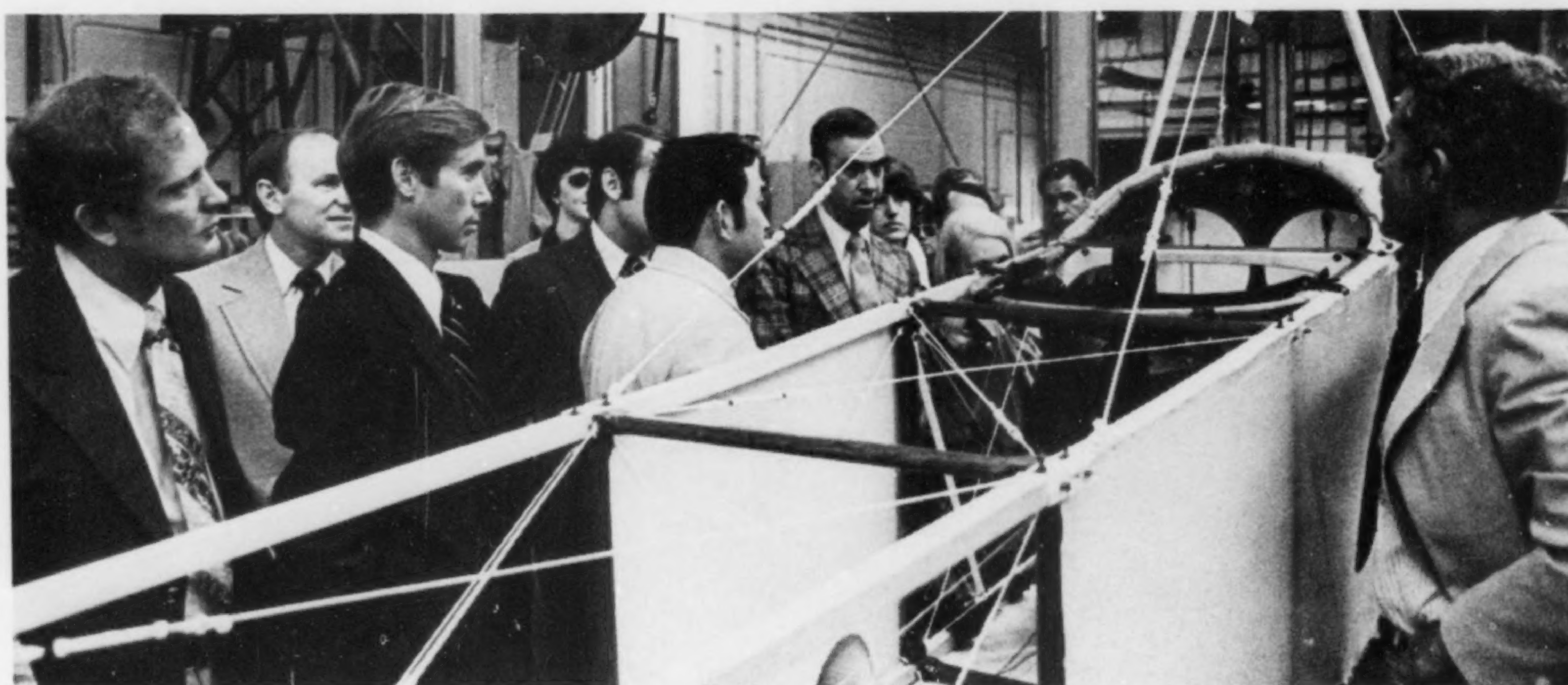
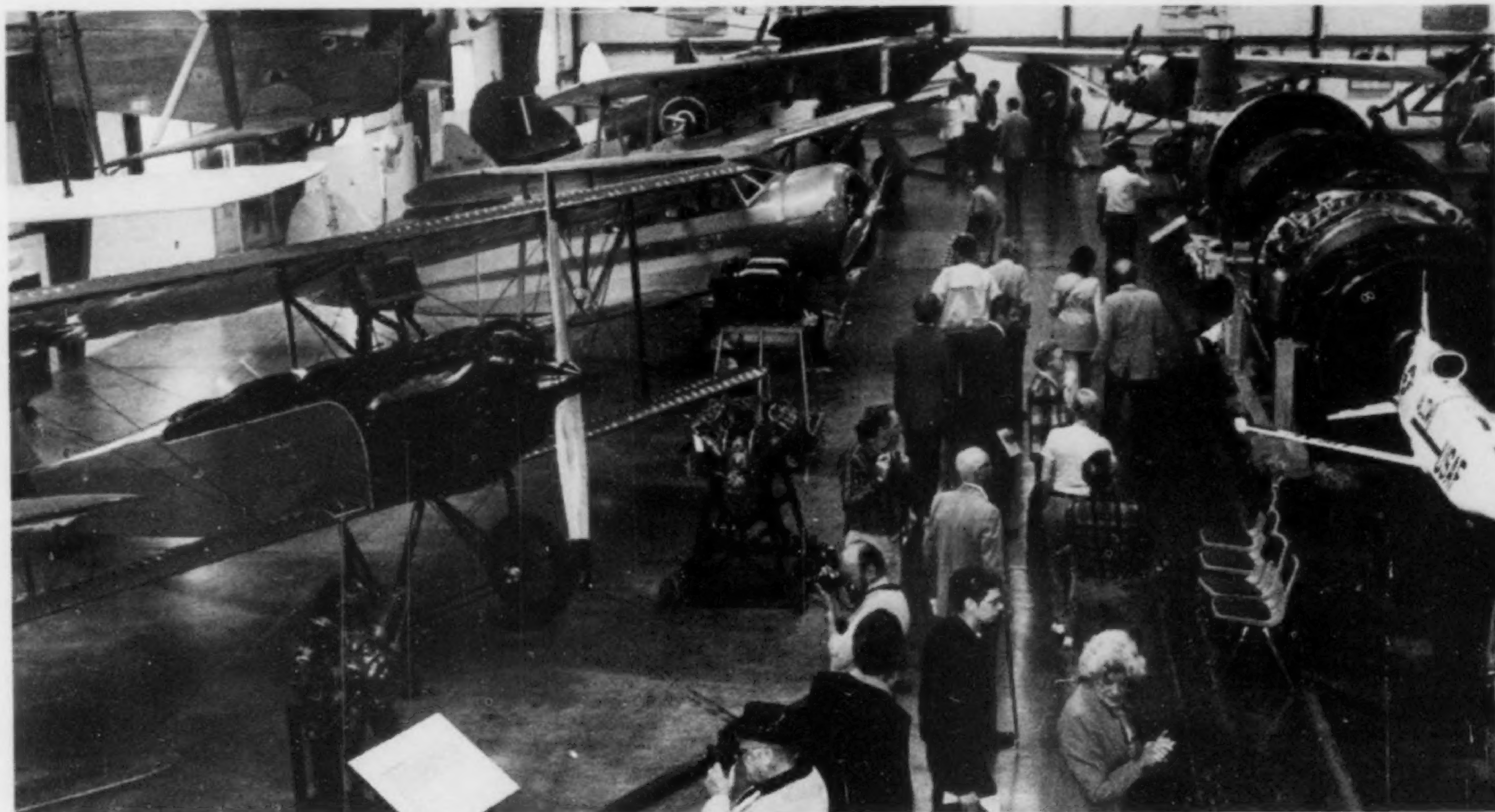
Wings and Things: Aviation Open House

April 16 and 17, 1983

Paul E. Garber Restoration Facility
10:00 a.m.-3:00 p.m.

The Paul E. Garber Preservation, Restoration, and Storage Facility in Suitland, Md., houses NASM's reserve collection of aircraft and spacecraft. More than 90 aircraft as well as numerous spacecraft, engines, propellers, and other flight-related objects are on display. Also included is a restoration workshop where skilled craftsmen restore everything from engines to aircraft interiors.

Usually open on a reservation-only basis, during this spring weekend three buildings will be open to the public. Trained Museum guides will be on hand to answer questions about the exhibits and artifacts.



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Smithsonian Institution
Washington, DC 20560
Room P-700

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